

KORESPONDENSI

1. Submitted to the journal (15-9-2021)
2. Revision: revision (29-11-2021)
3. Revised version received (6-10-2021) -
Revisions and Amends
4. Paper accepted for publication (24-10-2021)
-Final paper
5. Final proofreading before publication (5-11-2021)
6. Paper published (28-12-2021)

Submit for International Journal of Agricultural and Statistical Sciences

External

Inbox

A

Andi Dirpan <dirpan@unhas.ac.id> Sep 15, 2021, 11:11 AM

to rkishan05

Dear **Editor-in-Chief** of Journal of “International Journal of Agricultural and Statistical Sciences”.

I am writing to submit our manuscript entitled, “ **Extending of Mango (Mangifera Indica L.) Shelf Life with Combination of Zero Energy Cool Chamber (ZECC) Storage Technology, Washing and Packaging** ” for consideration for publication in Archives of Journal of “Journal of Agricultural and Statistical Sciences”.

Because our findings indicate that the maintenance of quality and the extension of the shelf life of mango fruit by (ZECC) which presented here, reveals that such ZECC can be considered for commercial application during storage and marketing, particularly for developing countries such as Indonesia. It might be useful when studying postharvest technology for mangos, particularly about ZECC which is low cost and eco-friendly. We hope this article is likely to be of great interest to postharvest technologists, scientists and researchers who read your journal.

This manuscript describes original work and is not under consideration by any other journal. All authors approved the manuscript and this submission.

Thank you for receiving our manuscript and considering it for review. We appreciate your time and look forward to your response.

Best regard

Andi Dirpan

Extending of Mango (*Mangifera Indica* L.) Shelf Life with Combination of Zero Energy Cool Chamber (ZECC) Storage Technology, Washing and Packaging ¹⁾

Andi Dirpan*, Muhammad Tahir Sapsal, Mulyati M Tahir, Muspirah Djalal and Ashabul Firdaus

*dirpan@unhas.ac.id

Department of Agricultural Technology, Hasanuddin University Makassar 90245, Indonesia

ABSTRACT

Mangoes suffer up to a 20%-50% shrinkage, loss, and quality damage as a result of improper harvest and post-harvest handling, as well as poor storage conditions. The presence of a post-harvest technology system of Zero Energy Cool Chamber (ZECC) storage combined with pre-handling treatment (washing and packaging) is one method of minimizing damage and extending the shelf life of mangoes. The purpose of this study was to determine the mango golek's quality and shelf life by using ZECC in combination with washing and packaging. This study used a completely randomized design (CRD) with factorial patterns, specifically factor A (storage type) and factor B (packaging and without packaging). The study's observation parameters were divided into two stages, with stage 1 consisting of physical parameters and stage 2 consisting of chemical, microbiological, and sensory parameters. According to preliminary research, the best treatment is washing with 1% detergent + 0.5 percent $\text{Ca}(\text{OH})_2$, which results in a smoother skin surface, less noticeable discoloration, and a cleaner surface free of sap and dirt. Physical, chemical, microbiological, and sensory analysis of mango golek (*Mangifera indica* L.) demonstrates that the ZECC storage technique can maintain fruit quality optimally in combination with washing (chemical) and packaging treatment processes, and it can effectively protect the mango golek's quality for up to 21 days.

Keywords: Mango, Quality, ZECC Storage

I. INTRODUCTION

1.1 Background

Indonesia possesses immense natural resource potential, particularly in horticultural crops like mango. According to the Indonesian Central Statistics Agency, mango production reached 2,431,329 tons per year in 2014 and 2,178,833 tons per year in 2015, a decrease of 10.39 percent. Mango productivity continues to be harmed by improper harvesting and post-harvest handling, which degrades the quality of the mangoes. Additionally, storage conditions are insufficient during agricultural product distribution and marketing, resulting in fruit depreciation. According to research conducted in developing countries, improper harvesting and post-harvest handling can result in fruit yield losses ranging from 20% to 50% (Dirpan et al. 2017)

Cold storage is one technique for postharvest handling. However, rural areas, which are typically agricultural centers, have severe shortages of cold storage, such as refrigerators. Additionally, the high operational costs associated with cold storage present a significant barrier to farmers employing post-harvest handlers. Additionally, it produces freon, an environmentally hazardous chemical (Dirpan

et al. 2017). In light of the aforementioned issues, we require an energy-free (zero energy) cold storage system that is also affordable (low cost) and environmentally friendly (eco friendly), one of which is the Zero Energy Cool Chamber (ZECC) (Islam and Morimoto 2015).

The Zero Energy Cool Chamber (ZECC) is a cost-effective and environmentally friendly method of storing fruits and vegetables following harvest. Due to the fact that ZECC does not require electricity to operate, it is frequently referred to as an environmentally friendly fruit and vegetable storage system (Dirpan 2019; Islam, Morimoto, and Hatou 2013) Additionally, this storage system is cost effective due to the fact that it makes use of readily available materials such as bricks, sand, plastic roofs, and water (Dirpan et al. 2017; Islam et al. 2013)

Recent years have seen an increase in research on fruit and vegetable storage methods utilizing ZECC, as demonstrated by Kamilia et al. (2017) and Dirpan et al. (2018) studies examining the quality of mangoes and tomatoes stored in ZECC (Ali 2017; Dirpan 2008). However, because fungi grew around the mangoes in the aforementioned studies, ZECC was used in conjunction with pre-handling treatments such as washing and

76 packaging to minimize the possibility of mold
77 and yeast growth and to extend the shelf life of
78 the golek mango. As a result, the purpose of
79 this research were: to determine the physical,
80 chemical, microbiological, and sensory
81 characteristics of mango golek stored in a
82 ZECC (Zero Energy Cool Chamber) in
83 combination with washing and packaging
84 processes and to determine the shelf life of
85 mangoes stored in a ZECC (Zero Energy Cool
86 Chamber) in combination with washing and
87 packaging processes.

88 II. Materials and Methods

89 II.1 Date and Location of Research

90 This research was conducted from July
91 to November 2019 at the Food Processing
92 Laboratory and the Chemical Laboratory of
93 Food Quality Analysis and Supervision of the
94 Food Science and Technology Study Program,
95 Department of Agricultural Technology,
96 Faculty of Agriculture, Hasanuddin
97 University, as well as at the Research Activity
98 Center (PKP) building and Lecturer Housing
99 Unhas Tamanlarea, Makassar.

100 II.2 Instruments and materials

101 The tools used in this research include a
102 zero energy cool chamber (ZECC),
103 polypropylene plastic packaging, fruit racks,
104 temperature and relative humidity sensors,
105 hoses, scales, analytical scales, and moisture,
106 analyzer, colorimeter, penetrometer, digital
107 hand refractometer, pH meter, stirring rod,
108 beaker, erlenmeyer flask, volumetric flask,
109 dropper pipette, volume pipette, petri dish,
110 autoclave, bulb, micropipet, test tube, tube
111 rack, laminar air flow (LAF), plates, spoons,
112 knives, rags, blenders.

113 Materials used in this study were 77
114 golek mango (main ingredient) with a maturity
115 index of 2 (light green), aquadest, detergent,
116 chlorine, calcium hydroxide ($\text{Ca}(\text{OH})_2$),
117 sodium hydroxide (NaOH), iodine, indicator
118 phenolphthalein, alcohol, buffer pH 7, mineral
119 water, starch indicator (starch), potato dextrose
120 agar (PDA) medium, inhibitor
121 (chloramphenicol), cotton, and labels.

122 II.3 Research procedure

123 The research process is as follows:

124 II.3.1 Preliminary research

125 Mangoes are sorted, and then those that
126 are not rotten or injured are selected for this
127 research. The mango is then graded according

128 to its maturity level. Following that, the Zero
129 Energy Cool Chamber (ZECC) is chemically
130 sterilized by spraying 0.5 percent chlorine +
131 70% alcohol. After that, the mangoes are
132 prepared and washed using water, detergent,
133 and $\text{Ca}(\text{OH})_2$ in accordance with the treatment
134 method. After washing, Mangoes were air-
135 dried and then stored in two different
136 conditions: ZECC and room temperature.

137 After that, the mango fruit was observed
138 daily for changes until the eighth day of
139 storage.

140 II.3.2 Main research

141 The following stage is mango that has
142 received the best treatment during the washing
143 process (1 percent detergent + 0.5 percent
144 $\text{Ca}(\text{OH})_2$), combined with post-harvest
145 technology, specifically packaging techniques
146 utilizing Polypropylene (PP) plastic, and then
147 returned to the sterilized ZECC. Each day, the
148 fruit is analyzed for damage, which is defined
149 as shriveling, softening, dull skin color, the
150 appearance of black spots on the fruit's skin,
151 and the presence of mold at the fruit's base.

152 II.4 Research design

153 The design of the research is divided into
154 two stages. The first stage is to determine the
155 optimal treatment for washing mangoes using
156 various washing ingredients, with the
157 following treatments:

158 A_0 : Control (Without washing)

159 A_1 : Water-based cleaning

160 A_2 : 1% detergent + 0.25 % $\text{Ca}(\text{OH})_2$

161 A_3 : 1% detergent + 0.5% $\text{Ca}(\text{OH})_2$

162 Following with storage in ZECC and at
163 room temperature, Physical parameters of the
164 fruit skin surface, color, sap, and impurities
165 were observed visually.

166 The next step is, mango that received the
167 best treatment during the washing process,
168 combined with packaging techniques utilizing
169 Polypropylene (PP) plastic. It is then analyzed
170 every three days using a variety of observation
171 parameters

173 II.5 Data analysis

174 The data obtained in the second phase of
175 the study were compiled using a completely
176 randomized design (CRD) with a factorial
177 pattern, namely factor A (type of storage) and
178 factor B (packaged and unpackaged). The
179 research was carried out with three
180 replications.

181 Data processing used quantitative
182 descriptive method, all parameters were
183 analyzed by analysis of variance (ANOVA)
184 with three replications. The differences for
185 each treatment were further tested using
186 Duncan's test. The software used for data
187 processing is Microsoft Excel 2016 and IBM
188 SPSS Statistics Version 23.

189 **II.6 Observation Parameter**

190 Observation parameters in stage 1 are
191 physical parameters of fruit skin surface, color,
192 sap and dirt. Parameters observed in stage 2
193 include vitamin C, pH value, water content,
194 total acid, total dissolved solids, weight loss,
195 skin color, hardness test, total microbe, and
196 organoleptic test using 15 panelists.

197

198 **III. RESULT AND DISCUSSION**

199 **III.1 First Phase of Research**

200 The results of the storage of mangoes
201 from the preliminary study showed that
202 mangoes stored at ZECC had better physical
203 quality (visually) than mangoes stored at room
204 temperature. Mangoes stored in ZECC had
205 smoother skin, less noticeable skin
206 discoloration until the 8th day of storage, fewer
207 lenticel spots, and did not grow fungus on the
208 skin surface. The fruit that was stored at room
209 temperature with a rougher skin surface
210 (wrinkled), slightly noticeable skin
211 discoloration, lenticel spots began to appear on
212 the 5th day of storage, as well as fungal growth
213 in some mango samples. These results indicate
214 that storage using the ZECC method is good
215 for extending the shelf life of mangoes
216 compared to storage at room temperature.

217 **III.1.1 Mango Skin Surface**

218 Visual observations of the mango skin's
219 surface revealed that ZECC storage was better
220 compared to room temperature storage. Mango
221 fruits stored in ZECC had smoother skin (not
222 wrinkled) than mango fruits stored at room
223 temperature, which had wrinkled skin surface.
224 The absence of wrinkles in mangoes stored at
225 ZECC is due to the relative humidity (RH) in a
226 good storage room, which is between 80% and
227 98.04 percent, as opposed to room
228 temperature, which has a relative humidity of
229 50% to 56.90 percent. This is consistent with
230 Muchtadi (1992), who states that all varieties
231 of mango are susceptible to cold damage in the
232 form of dark spots, uneven ripening, and

233 failure to produce adequate flavor and color,
234 and that a relative humidity of 85-90 percent is
235 required to prevent wilting and softening of
236 various fruits and vegetables (Muchtadi 1992).

237 The room temperature is higher than the
238 temperature in the ZECC. ZECC has a
239 temperature range of 24-25°C, while the
240 ambient temperature ranges from 26-31°C.
241 Mango fruit stored at room temperature
242 transpired and respired at a faster rate than
243 mango stored in ZECC, causing the mango
244 skin to wrinkle. Because respiration rate is
245 related to the rate of quality deterioration, it
246 can be used to estimate the shelf life of fruit
247 after harvest. As stated by Rizkia (2004) that
248 the slower the rate of respiration, the longer the
249 fruit can be stored in its fresh state; conversely,
250 the faster the rate of respiration, the shorter the
251 shelf life (Rizkia 2004).

252 **III.1.2 Skin color**

253 Mangoes are generally observed visually
254 by observing how clearly the color change
255 from green to yellow appears on the mango
256 skin. Mangoes stored at room temperature and
257 in ZECC without treatment/washing (control),
258 as well as those washed with water and
259 detergent + Ca(OH)₂ exhibited no discernible
260 color changes. On the sixth day of observation,
261 the color changed to a slight yellow hue. This
262 color change occurs because mangoes, as
263 climacteric fruits, accelerate the ripening
264 process during storage. The maturation process
265 that occurs concurrently with the breakdown of
266 chlorophyll, resulting in the appearance of
267 other color pigments such as yellow and red,
268 causing the green color to degrade. This is in
269 line with El-Zeftawi *et al.*, (1988), who stated
270 that the level of chlorophyll content in green
271 fruit decreases during the storage, other
272 pigments begin to appear, turning the fruit
273 yellow or orange (El-Zeftawi et al. 1988).

274 **III.1.3 Sap and Dirt**

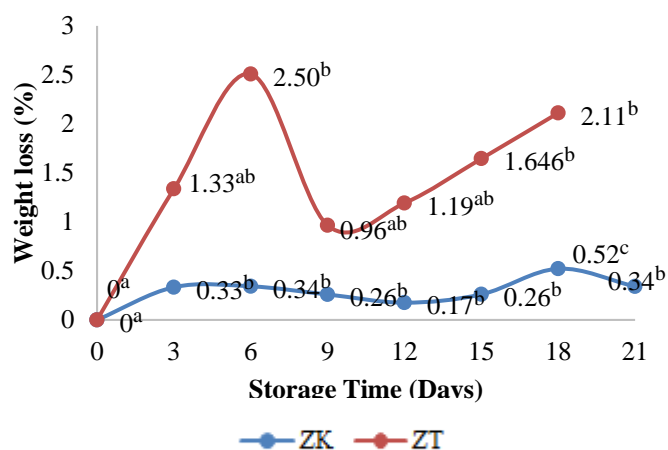
275 For mango fruit washed with water, on
276 day 6 DAW (day after washing), there were
277 still remnants of sap attached to the surface of
278 the mango fruit skin, although they were not
279 particularly noticeable. However, there were a
280 few lenticel spots and a change in color at the
281 fruit's base on day 6 DAW (day after washing)
282 until the 8th day of DAW. While mangoes
283 treated with 1% detergent + 0.25 percent
284 Ca(OH)₂ can visually remove sap, the
285 treatment was more effective at 1% + Ca(OH)₂
286 0.5 percent detergent immersion, which

287 resulted in samples of mango fruit being more
 288 free of sap and dirt, resulting in a smoother
 289 surface with no noticeable changes up to 8
 290 DAW. This is because 1% detergent binds to
 291 oil and effectively removes or lifts dirt. Until
 292 the eighth day after DAW mango was treated
 293 with 1% detergent and 0.5 percent $\text{Ca}(\text{OH})_2$, no
 294 lenticel or fungal spots appeared at the base or
 295 on the surface of the fruit skin. The surface is
 296 smoother and burn-free because the detergent's
 297 surfactant active ingredients can remove the oil
 298 contained in the sap. Alkaline $\text{Ca}(\text{OH})_2$
 299 solution can neutralize the acid in the sap
 300 attached to the golek mango cultivar's skin.
 301 This is consistent with Ahmad, S et al (2017)'s
 302 finding that the 1% + $\text{Ca}(\text{OH})_2$ 0.5 percent
 303 detergent treatment resulted in a lower mean
 304 score for reducing lenticel spots at 2 to 14
 305 DAW when compared to the control (Ahmad
 306 et al. 2017). In accordance with Taqiyyah
 307 (2015), a combination of detergent and
 308 $\text{Ca}(\text{OH})_2$ is capable of removing sap and oil
 309 from the surface of the Gedong mango skin
 310 (Taqiyyah 2015).

311 III.2 Second Phase of Research

312 The second stage of this study involved
 313 determining the quality and shelf life of
 314 mangoes while they were stored. Mangoes that
 315 received the best washing treatment (1 percent
 316 detergent + 0.5 percent $\text{Ca}(\text{OH})_2$) were then
 317 given packaging treatment (using
 318 Polypropylene (PP) plastic and without
 319 packaging) and then analyzed for quality.
 320 Mangoes packaged with Polypropylene (PP)
 321 plastic can be stored in ZECC for 21 days,
 322 whereas mangoes packaged without
 323 Polypropylene plastic have a shelf life of only
 324 18 days.

325 III.2.1 Weight Loss

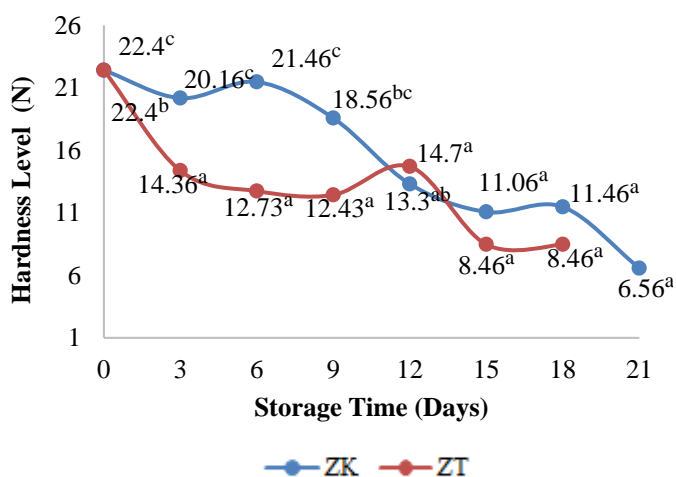


327 Figure 1. The weight loss of Mangoes During Storage. Values
 328 followed by different letters indicate treatment results that are
 329 significantly different ($p < 0.05$).

330 During storage, the mango fruit's weight
 331 loss tends to increase. Unpackaged mangoes
 332 (ZT) lost approximately twice as much weight
 333 as packaged mangoes (ZK). This means that
 334 when packaging is used in combination with
 335 the ZECC storage technique, mangoes lose less
 336 weight. Unpackaged mangoes experienced a
 337 greater increase in weight loss due to a high
 338 evaporation rate (transpiration), whereas
 339 packaged mangoes experienced less water
 340 evaporation during storage. Water loss results
 341 in withering and shrinking. This is consistent
 342 with Winarno (2002), who states that the
 343 amount of water in foods determines their
 344 freshness, appearance, and durability
 345 (Winarno 2002). If some of the water in the
 346 food evaporates, weight loss occurs, reducing
 347 the food's freshness, appearance, and
 348 durability.

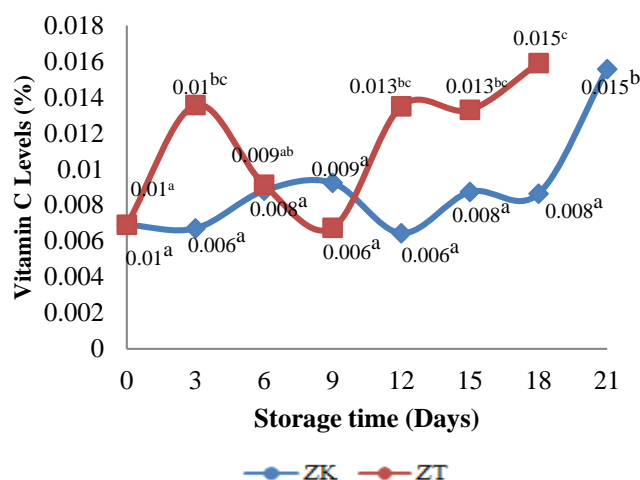
349 In addition to transpiration, weight loss
 350 is also influenced by the respiration process of
 351 mango fruit. Carbon loss can occur during the
 352 respiration process. Carbon compounds
 353 contained in the sugar in mangoes will bind
 354 and react with oxygen which will produce
 355 simple volatile compounds, namely water
 356 vapor and carbon dioxide so that the fruit will
 357 lose its weight. So in this case it is known that
 358 the respiration process can be suppressed by a
 359 combination of packaging and storage in
 360 ZECC. This is in accordance with the opinion
 361 of Syafutri et al., (2006), which states that the
 362 process of fruit respiration can be suppressed
 363 by combining packaging and storage at low
 364 temperatures (Syafutri, Pratama, and Saputra
 365 2006).

370 III.2.2 Hardness Level



410
411
412
413

III.2.3 Vitamin C levels



414
415
416
417

Figure 3. Vitamin C Levels of Mangoes During Storage. Values followed by different letters indicate treatment results that are significantly different ($p < 0.05$).

418 The levels of vitamin C (ascorbic acid)
419 of mangoes during storage in ZECC tend to
420 vary, both packaged in polypropylene plastic
421 and mangoes without packaging. The
422 significant increase in vitamin C levels of
423 unpackaged mangoes until the end of storage
424 was in line with the faster ripening process of
425 mangoes compared to packaged mangoes. This
426 is in accordance with Pantastico (1986), which
427 states that ripe fruit will increase in acidity, and
428 this increase occurs simultaneously with the
429 climacteric pattern, while vitamin C levels will
430 decrease when the maximum point of increase
431 has been exceeded (withering stage)
432 (Pantastico 1986). The ripening process of
433 unpackaged mangoes is faster because the
434 respiration process is greater than that of
435 packaged mangoes. Mango packaging can
436 regulate/minimize the respiration process of
437 the fruit so that the freshness of the mango can
438 be maintained. This is in accordance with Park
439 et al., (2004), which states that Polypropylene
440 (PP) plastic has high permeability properties
441 which can regulate the rate of atmospheric
442 absorption or respiration rate which can
443 maintain fruit freshness longer (Park, Kim, and
444 Yun 2004). The results of analysis of variance
445 showed that mango without packaging
446 treatment and mango with packaging treatment
447 had a significant effect on vitamin C levels
448 during storage. This is indicated by the value
449 of vitamin C which was initially low and then
450 increased until the end of storage. The increase

371
372
373
374

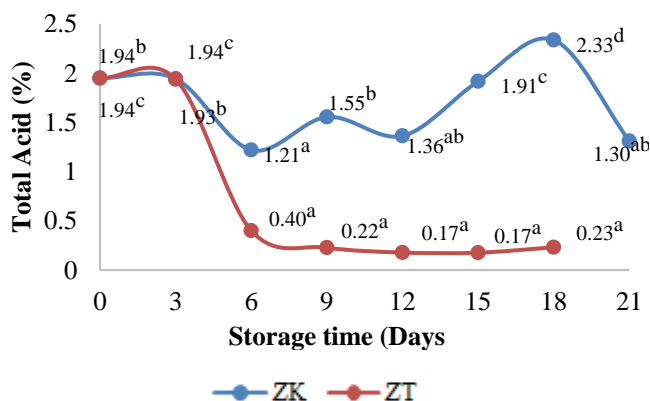
Figure 2. The Hardness Level of Mango Fruit During Storage. Values followed by different letters indicate treatment results that are significantly different ($p < 0.05$).

375 The ripening process of mangoes during
376 storage results in changes in the level of mango
377 fruit hardness. The ripening process in
378 mangoes occurs concurrently with the
379 conversion or degradation of protopectin to
380 pectin, resulting in a decrease in cell wall
381 rigidity. Mangoes without packaging treatment
382 (ZT) had a greater loss of hardness than
383 mangoes with packaged treatment (ZK). This
384 is due to the fact that unpackaged mangoes
385 have a higher respiration rate and a higher
386 enzyme activity. The more actively these
387 enzymes are, the softer the texture of the fruit.
388 Meanwhile, the rapid rate of respiration causes
389 the fruit tissue to rupture, resulting in the
390 mango becoming soft. The mango with
391 packaging treatment (ZK) can reduce the
392 amount of oxygen received, thereby slowing
393 the respiration process (maintained). This is
394 consistent with Syafutri et al. (2006), who state
395 that the decrease in hardness is also a result of
396 the respiration and transpiration processes
397 (Syafutri et al. 2006). The respiration process
398 results in the breakdown of carbohydrates into
399 simple compounds and tissue rupture, resulting
400 in the mango becoming soft, whereas the
401 transpiration process results in water
402 evaporation, resulting in the mango becoming
403 wilted.

404
405
406
407
408
409

451 or decrease in vitamin C is because the vitamin
 452 is unstable, easily oxidized when exposed to
 453 air (oxygen) and this process can be
 454 accelerated by storage temperature. This is in
 455 accordance with Tannenbaum (1976), stating
 456 that the reduction of O₂ will inhibit the
 457 degradation of ascorbate into dehydroascorbic
 458 acid and H₂O₂ (Tannenbaum 1976) . The
 459 resulting H₂O₂ will cause autoxidation so that
 460 it will increase the damage of vitamin C.

461 III.2.4 Total Acid



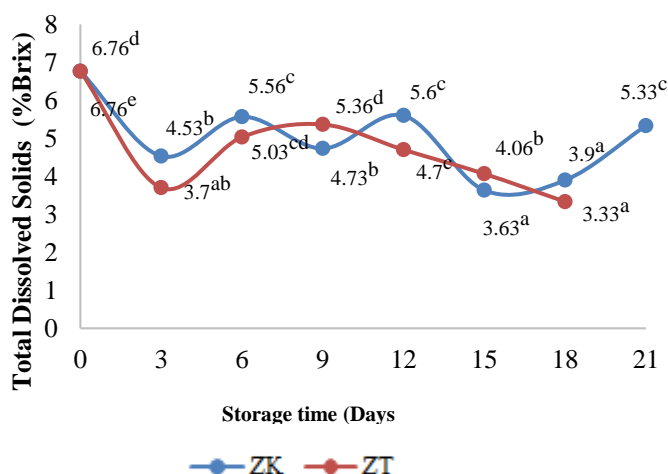
462 Figure 4. Total Acid Level of Mango Fruit During Storage.
 463 Values followed by different letters indicate treatment results
 464 that are significantly different (p<0.05).
 465

466 The total acid value of mango in ZECC
 467 storage, both packaged and unpackaged, tends
 468 to decrease, though the trend is variable. The
 469 percentage of total acid in the fruit decreases as
 470 the fruit is stored. The decrease in the
 471 percentage of total acid is due to the respiration
 472 process's use of organic acids, as well as the
 473 use of organic acids by microbes in energy-
 474 consuming activities. This energy is obtained
 475 through the breakdown of the nutrients found
 476 in food. Organic acids are converted to sugars
 477 during the respiration process. Amalya et al.
 478 (2017) found in their research that the fruit's
 479 decreased organic acid value indicated that the
 480 fruit's ripening metabolism was functioning
 481 normally (Khairi, Falah, and Pamungkas
 482 2017).

483 Total acid in mangoes that were not
 484 packaged (ZK) contained a greater proportion
 485 of total acid or degraded more rapidly than in
 486 packaged mangoes (ZK). This is due to the
 487 respiration process of unpackaged mangoes.
 488 Merynda et al. (2006) state that when mangoes
 489 are not packaged, the respiration process
 490 cannot be minimized due to the abundant O₂ in
 491 the environment (Syafutri et al. 2006).

492 III.2.5 Total Dissolved Solids (TDS)

493 Mangoes' total dissolved solids
 494 (packaged and unpackaged) exhibit a
 495 fluctuating graph. Unpackaged mangoes (ZT)
 496 underwent a maximum ripening process, as
 497 indicated by the percentage of TDS value
 498 increasing significantly at first and then
 499 gradually decreasing until the end of storage.
 500 The increase in TDS is a result of starch
 501 hydrolysis during ripening process. While the
 502 decrease in TDS occurs as a result of the
 503 abundant O₂ available in the environment,
 504 which prevents the respiration process from
 505 being suppressed. Thus, glucose as the result
 506 of starch hydrolysis then was consumed during
 507 the respiration process, resulting in a rapid
 508 decrease in the sugar content of the fruit.
 509 Pantastico (1993) confirms this by stating that
 510 during ripening, starch is hydrolyzed into
 511 simple compounds that serve as a source of
 512 energy during the respiration process
 513 (Pantastico 1986). At this point, the sucrose
 514 has been converted back to glucose and
 515 fructose. The decrease in total sugar content of
 516 unpackaged mangoes occurred as the mango
 517 fruit began to ripen, at which point the starch
 518 content began to decrease and the activity of
 519 the invertase enzyme decreased, resulting in a
 520 decrease in sugar content. The mango with
 521 packaging (ZK) has the ability to maintain the
 522 fruit's ripening process, as indicated by the
 523 predominant fluctuating TDS value. This
 524 demonstrates that by combining packaging and
 525 storage in ZECC, the rate of decrease in the
 526 percentage of TPT in mangoes can be slowed.



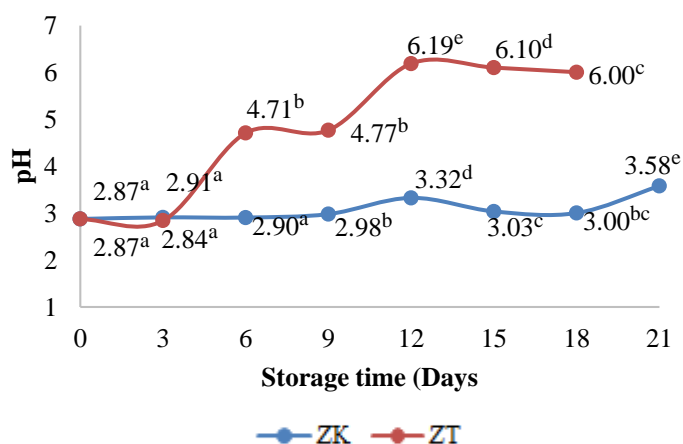
527 Figure 5. Total Dissolved Solids of Mango Fruit During
 528 Storage. Values followed by different letters indicate treatment
 529 results that are significantly different (p<0.05).
 530

531 This variable total dissolved solids value
 532 is also a result of the fruit's non-uniform
 533 maturity level. Non-uniform fruit ripeness
 534 causes abnormal respiratory activity so that the

535 breakdown process of simple sugars varies. In
 536 general, changes in total dissolved solids
 537 content increased at the maximum point of
 538 storage and then decreased until the fruit began
 539 to rot on the final day of storage. This is
 540 consistent with Biale and Young's (1971)
 541 observation that the general trend is for a rapid
 542 increase in sugar content followed by a
 543 decline; in climacteric fruit, this condition
 544 becomes a marker (Biale and Young 1971).

545 III.2.6 Degree of Acidity (pH)

546 According to the graph, mango fruit are
 547 acidic, with a pH value ranging between 2 and
 548 6 during storage. The ripening of mangoes
 549 alters the pH value of the fruit. Without
 550 packaging treatment (ZT), mango matured
 551 rapidly (maximum), increasing the pH value. It
 552 is not the case with packaged mangoes (ZK),
 553 as their ripening process is slowed, resulting in
 554 a stable pH value throughout storage. As the
 555 mango ripens, the acid content decreases while
 556 the simple sugars increase, as indicated by the
 557 decrease in total acid content. The pH value is
 558 directly proportional to vitamin C levels and
 559 inversely proportional to total acidity, as
 560 shown in the graph. This is consistent with
 561 Amalya et al., (2017), who state that changes
 562 in pH indicate changes in the composition of
 563 the fruit's cell fluid as it matures; the pH value
 564 that tends to be high is related to relatively high
 565 ascorbic acid (vitamin C) levels during
 566 storage; this change indicates that the fruit's
 567 metabolism affects the pH value (Khairi et al.
 568 2017).

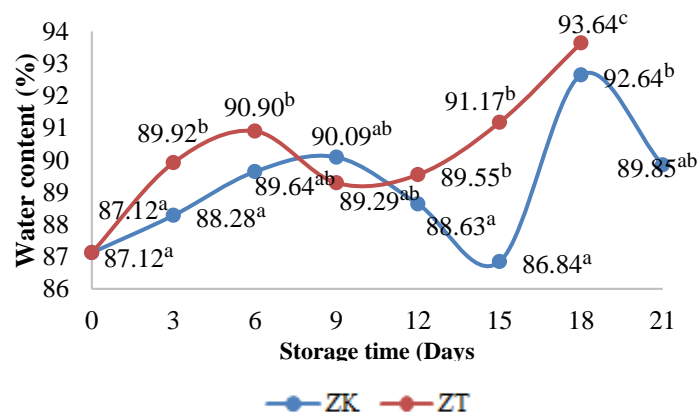


569
 570 Figure 6. pH Value (Degree of Acidity) Mango Fruit During
 571 Storage. Values followed by different letters indicate treatment
 572 results that are significantly different (p<0.05).

573 III.2.7 Water content

574 The water content of mangoes stored in
 575 the ZECC method varied slightly during
 576 storage. When compared to unpackaged
 577 mangoes, packaged mangoes (ZK) are able to

578 maintain changes in water content during
 579 storage. This is because PP packaged mangoes
 580 have a high permeability, which minimizes
 581 changes in water content during storage. This
 582 is consistent with Schwartz (2009), who states
 583 that because of the packaging, ambient air
 584 cannot easily enter the material, thereby
 585 inhibiting the process of water exchange
 586 during storage (Schwartz 2009).



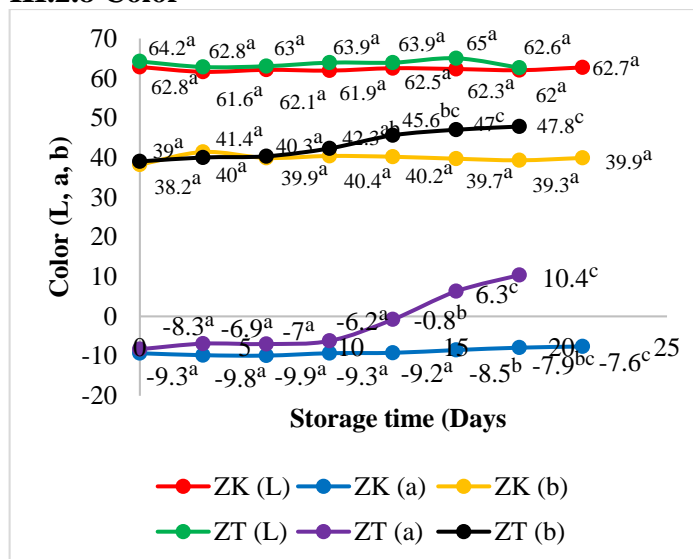
587
 588 Figure 7. Water Content of Mangoes During Storage. Values
 589 followed by different letters indicate treatment results that are
 590 significantly different (p<0.05).

591 Due to the high humidity in ZECC
 592 storage, which reached 80-90 percent, mango
 593 fruit experienced an increase and decrease in
 594 water content during storage. Due to the high
 595 humidity level in the ZECC room, moisture
 596 absorption from the environment into the
 597 stored mango is possible. The longer the
 598 storage time, the higher the water content will
 599 remain. According to Herawati (2008), a
 600 significant factor influencing the decline in the
 601 quality of food products is changes in the
 602 product's water content, which can be
 603 influenced by the room's temperature and
 604 humidity during storage (Herawati 2008). This
 605 opinion is backed up by Retnani et al., (2009),
 606 who state that the high humidity of the storage
 607 room can result in the absorption of water
 608 vapor from the air into the foodstuffs, resulting
 609 in an increase in water content (Retnani et al.
 610 2009).

611 Additionally, the increase in water
 612 content during storage is a result of the
 613 mangoes' respiration process. During storage,
 614 the fruit undergoes a ripening process that
 615 includes the conversion of starch to simple
 616 sugars (C₆H₁₂O₆). These simple sugars then
 617 interact with the oxygen (O₂) in the chamber,
 618 increasing the rate of water (H₂O) formation in
 619 the fruit. This is consistent with Nurhayati S
 620 (2004), who states that one of the causes of
 621 changes in the water content of fruit is the

622 respiration process, during which water is
 623 formed as a result of sugar reorganization into
 624 simpler compounds.

625 III.2.8 Color



626 Figure 8. Analysis of Mango Skin Color During Storage.
 627 Values followed by different letters indicate treatment results
 628 that are significantly different ($p < 0.05$).
 629

630 The L* value indicates the brightness
 631 level of the mango fruit, which indicates the
 632 reflected light that produces achromatic colors
 633 of white, gray and black, ie from a value of 0
 634 (black) – 100 (white). The L* value of
 635 unpackaged and packaged mangoes had a very
 636 small decrease in lightness value during
 637 storage. The range of changes in the L* value
 638 from 65-62 indicates a slight decrease in
 639 brightness level during storage. The longer the
 640 fruit is stored, the lower the brightness level of
 641 the mango. According to Ahmad et al., (2014),
 642 that the brightness level of the color will
 643 decrease which will be directly proportional to
 644 the longer the shelf life, the fruit will lead to
 645 spoilage in the end (Ahmad, Darmawati, and
 646 Refilia 2014). The decreasing brightness level
 647 of the mango skin color is caused by changes
 648 in the chlorophyll content of the fruit. This is
 649 in accordance with the statement of Syafutri et
 650 al., (2006), which states that the reduced level
 651 of color brightness in fruit during storage is
 652 caused by reduced chlorophyll content in fruit
 653 skins and the appearance of carotenoids
 654 (Syafutri et al. 2006).

655 The a* value is a value that shows the
 656 gradation of green to red. A mixed red-green
 657 chromatic color with a value of +a* (positive)
 658 from 0 to +80 for red and a value of -a*
 659 (negative) from 0 to -80 for green. The a* value
 660 of mango tends to increase during the storage
 661 process. Mangoes tend to be green, indicated
 662 by an a* value below 0, but the longer the

663 storage time, the color of the fruit moves to red.
 664 The significant increase in a* value was caused
 665 by the high respiration rate of unpackaged
 666 mangoes so that the degradation of chlorophyll
 667 was also rapid which had the effect of
 668 accelerating the synthesis of pigment (color
 669 change) of the fruit. This is in accordance with
 670 the opinion of Masfufatun et al. (2015), which
 671 states that a high respiration rate will also
 672 cause chlorophyll degradation and pigment
 673 synthesis to be fast, consequently accelerating
 674 color changes (Masfufatun, Kumala, and
 675 Rahayuningsih 2009).

676 The b* value indicates the color
 677 gradation to yellow. A mixed blue-yellow
 678 chromatic color with a +b* (positive) value
 679 from 0 to +70 for yellow and a -b* (negative)
 680 value from 0 to -70 for blue. Based on the
 681 graph above, it shows that unpackaged
 682 mangoes have a slowly increasing b* value
 683 during storage compared to packaged mangoes
 684 whose b*_ values tend to be stable until the end
 685 of storage. The results of the measurement of
 686 the b* value show that the longer the storage,
 687 the yellow color of the mango will be clearer.
 688 The increasing b* value in unpackaged
 689 mangoes indicates that the fruit is getting more
 690 mature than the packaged mangoes during
 691 storage. This is in accordance with the
 692 statement of Kusumiyati et al., (2018), which
 693 states that the longer the storage, the yellow
 694 color of the mango is more clearly marked by
 695 the higher the mean b* value. The higher the
 696 b* value in the mango can be indicated the
 697 higher the ripeness level of the fruit
 698 (Kusumiyati et al. 2018).

699

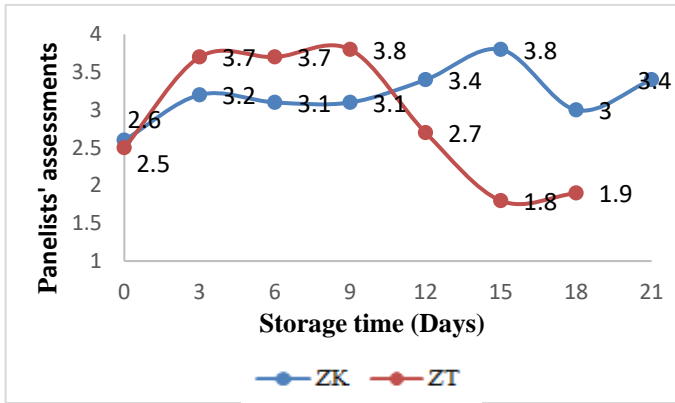
700

701

702

703 III.2.9 Organoleptic test

704 III.2.9.1 Color

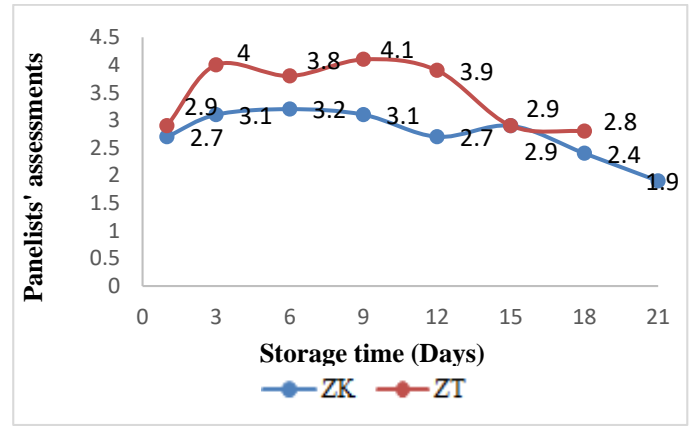


705
706 Figure 9. Results of Organoleptic Testing on Mango Color in
707 ZECC Storage

708 The changes in panelists' assessments of
709 organoleptic color parameters in mangoes
710 were due to the nature of mangoes undergoing
711 post-harvest ripening (after harvesting),
712 specifically that the color will change during
713 the storage process due to chlorophyll
714 degradation into other pigments. The panelists'
715 assessment of mangoes with packaging
716 treatment (ZK) tended to remain stable until
717 the end of storage, with an average value of 3
718 (slightly similar), whereas mangoes without
719 packaging (ZT) maintained an average value
720 of 4 (similar) until the ninth day of storage,
721 when it decreased until the end of storage. This
722 demonstrates that mangoes treated with
723 packaging can help preserve or delay the color
724 change of mangoes stored in ZECC. Packaging
725 treatment on mangoes can slow the respiration
726 process, resulting in a slower color change and
727 maturation and aging process. This is
728 consistent with Kamilia (2017), who states that
729 a faster respiration rate can accelerate the
730 senescence process, which results in a more
731 rapid color change.

732 III.2.9.2 Aroma

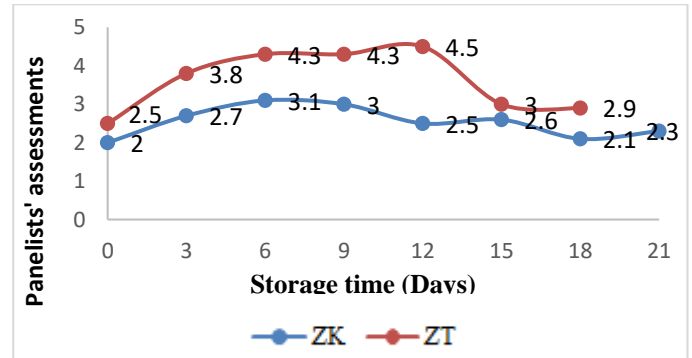
733 The panelists' evaluations of the mango
734 aroma parameters revealed a range of results
735 but a consistent pattern of increasing and then
736 decreasing until the end of storage. In terms of
737 fruit aroma, panelists prefer the unpackaged
738 aroma of mango fruit.



739
740 Figure 10. Results of Organoleptic Testing on Mango Aroma
741 in ZECC Storage

742 The high acceptance of unpackaged
743 mango aroma (ZT) is a result of the increasing
744 ripening process (perfect ripening), which
745 results in an increase in the production of
746 volatile components.
747 While the packaged mango (ZK) took longer
748 to decompose, the panelists generally disliked
749 it due to the incomplete ripening process,
750 which resulted in a low flavor. This is
751 consistent with Muchtadi (1992), who stated
752 that ripening typically results in an increase in
753 the content of simple sugars, which imparts a
754 sweet flavor, as well as an increase in the
755 production of volatile substances, which
756 imparts a distinctive fruit flavor.

757 III.2.9.3 Taste



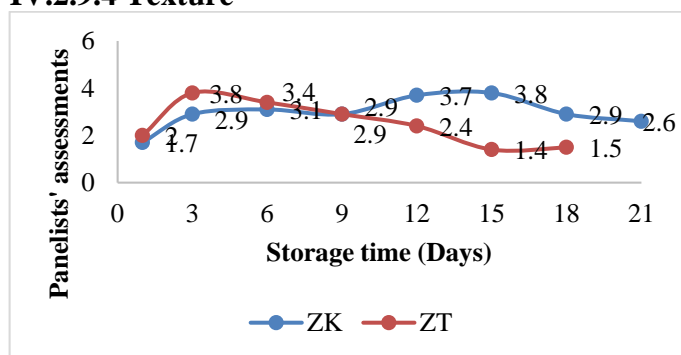
758
759 Gambar 11. Results of Organoleptic Testing on Mango Taste
760 in ZECC Storage

761 The results of organoleptic tests on
762 mangoes stored at ZECC showed that the
763 panelists' assessment of fruit taste increased
764 and then decreased until the end of storage.
765 The range of values between 3-5 (based on the
766 graph) shows that the panelists' assessment of
767 unpackaged mangoes (ZT) is dominantly
768 preferable to mangoes with packaged
769 treatment (ZK) with a value of 2-3. The high
770 rating for unpackaged mangoes is because the
771 mangoes undergo an even ripening process
772 during storage, resulting in a distinctive taste
773 and good color which are preferred by

774 panelists (Ali 2017). The sweet taste is due to
 775 the change in the starch content of the fruit to
 776 sugar during storage. This is in accordance
 777 with the statement of Mulyati (2012), that
 778 changes during the ripening process are
 779 changes in starch and fat reserve materials into
 780 various sugars (Mulyati 2012). The mango
 781 with packaging (ZK) undergoes a slow
 782 ripening process due to its low respiration rate
 783 in the presence of packaging, but it takes
 784 longer to decay or damage in ZECC storage.

785
786
787
788
789

790 **IV.2.9.4 Texture**



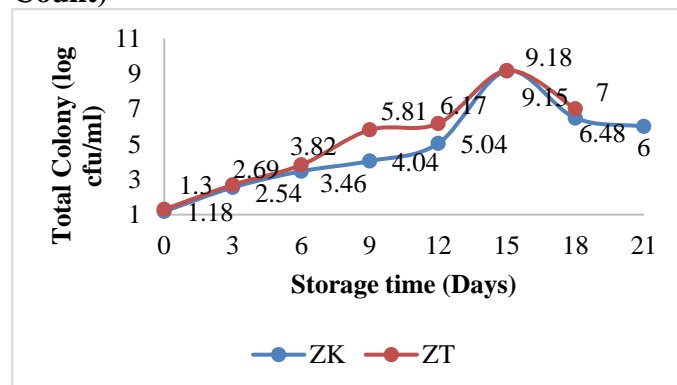
791 Figure 12. Results of Organoleptic Testing on Mango Texture
 792 in ZECC Storage
 793

794 Panelists determined that mango with
 795 packaged treatment (ZK) (mean value 3-4) was
 796 preferable in terms of texture because the level
 797 of hardness did not decrease significantly
 798 (soft), as opposed to mango without packaged
 799 treatment (ZT) (mean value 2-3). The texture
 800 began as hard, which the panelists disliked,
 801 then softened slightly, which the panelists
 802 liked, and finally became extremely soft due to
 803 damage/rotting, which the panelists disliked.
 804 When the qualitative (organoleptic test of
 805 texture parameters) analysis of mango fruit is
 806 combined with quantitative analysis (with a
 807 penetrometer), it is discovered that the level of
 808 hardness (the process of hardness decreasing)
 809 is directly proportional during storage.

810 Mangoes' softening texture is caused by
 811 the ripening process that occurs during storage.
 812 Maturation occurs concurrently with the
 813 conversion or degradation of insoluble
 814 protopectin to soluble pectin. The reshuffle
 815 occurs as a result of the action of enzymes such
 816 as pectin methyl esterase, which softens the

817 fruit. Proteopectin levels in the fruit decrease
 818 as the fruit ripens, while pectin levels increase.
 819 This is in accordance with Afrazak et al.,
 820 (2014), that as fruit ripens and stores, some of
 821 the water-insoluble protopectin converts to
 822 water-soluble pectin, reducing the cohesion of
 823 the cell walls that connect cells, resulting in a
 824 decrease in texture or fruit hardness and the
 825 fruit becoming soft (Johansyah and
 826 Kusdiantini 2014). Additionally, the rate of
 827 respiration has an effect on the degree of
 828 hardness or texture. Unpackaged mangoes
 829 with a high respiration rate cause the fruit's
 830 tissue to rupture and enzyme activity to
 831 accelerate, resulting in a softer fruit texture.
 832 The mango with packaging treatment (ZK) can
 833 reduce the amount of oxygen received, thereby
 834 slowing the respiration process (maintained).

835 **III.2.10 Microbial Analysis (Yeast Mold
 836 Count)**



837 Figure 13. Mold and Yeast cell count on Mangoes During
 838 Storage in ZECC
 839

840 According to the graph, the results of
 841 microbial analysis (mold and yeast counts) on
 842 mango fruit storage in ZECC indicated that
 843 yeast mold growth continued to increase and
 844 then decreased gradually until the end of
 845 storage. Microbial growth (mold and yeast)
 846 that began low/small and then increased to a
 847 maximum growth peak on the 15th day
 848 generally indicated that the mangoes' quality
 849 deteriorated during storage and gradually
 850 entered the senescence phase. This also
 851 demonstrates that mangoes with a relatively
 852 high sugar content and a low pH provide an
 853 ideal environment for molds and yeasts to
 854 grow to their maximum growth capacity
 855 during storage. This is consistent with Seema
 856 R (2015) statement that fruit with a high sugar
 857 content and a low/acidic pH (pH range
 858 between 3-8) promotes the growth of fungi
 859 (mold/yeast) after the fruit is harvested (Rawat
 860 2015).

861 Mango without packaging (ZT)
862 exhibited a greater increase in the growth of
863 the dominant mold/yeast than mango with
864 packaging (ZK). This demonstrates that by
865 combining calcium hydroxide washing with
866 packaging on mangoes stored in ZECC, the
867 rate of microbial growth can be slowed or
868 suppressed, thereby extending the fruit's life
869 phase. Certain microbes require oxygen to
870 grow, which can be suppressed through
871 packaging. This is consistent with the opinion
872 of Ira M et al. (2017), who state that treating
873 fruit with packaging technology can suppress
874 the air activity required by microbes, thereby
875 slowing the growth rate of pathogenic
876 microbes (Mulyawanti, Syaefullah, and
877 Amiarsi 2018)

878 879 880 **IV. Conclusions**

881
882 It can be concluded that analysis of the
883 quality of golek mango (*Mangifera indica* L.)
884 physically, chemically, microbiologically, and
885 sensory in the Zero Energy Cool Chamber
886 (ZECC) storage technique shows that ZECC
887 can maintain optimal fruit quality through a
888 washing treatment process (chemically) in
889 combination with packaging. In addition, the
890 Zero Energy Cool Chamber (ZECC) storage
891 method with a combination of washing and
892 packaging treatments is effective in
893 maintaining the quality of mangoes up to 21
894 days of storage.

895 896 **V. Acknowledgment**

897 This research was funded by the
898 Directorate General of Research and
899 Development, Ministry of Research,
900 Technology and Higher Education,
901 Republic of Indonesia, through LPPM
902 Unhas : Penelitian Terapan 2020.

903 **References**

904 Ahmad, Sutopo, Roedhy Poerwanto, and
905 Suryo Wiyono. 2017. "Keefektifan
906 Bahan Pencuci Dan Pencegah Penyakit
907 Terhadap Kualitas Buah Mangga CV.
908 Gedong Gincu Dan Arumanis (The
909 Effectiveness of Washing Materials and
910 Disease Protecting Agent on the Quality
911 of Mango Fruit Cv. Gedong Gincu and

912 Arumanis)." *Jurnal Hortikultura*
913 27(2):253–60.

914 Ahmad, Usman, Emmy Darmawati, and Nur
915 Rahma Refilia. 2014. "Kajian Metode
916 Pelilinan Terhadap Umur Simpan Buah
917 Manggis (*Garcinia Mangostana*) Semi-
918 Cutting Dalam Penyimpanan Dingin." *Jurnal Ilmu Pertanian Indonesia*
919 19(2):104–10.
920

921 Ali, Kamilia Nur Yaumil. 2017. "Mutu Buah
922 Mangga (*Mangifera Indica* L.) Dan
923 Tomat (*Lycopersicum Esculentum* Mill.)
924 Yang Disimpan Pada ZECC (Zero
925 Energy Cool Chamber)." Universitas
926 Hasanuddin.

927 Biale, J. B. and R. Young. 1971. *The Avocado*
928 *Pear. Dalam Hulme, A.C. The*
929 *Biochemistry of Fruit and Their Produce.*
930 London: Academic Press.

931 Dirpan, A. 2019. "The Quality of Tomato
932 (*Lycopersicum Esculentum* Mill.) Stored
933 on ZECC (Zero Energy Cool Chamber)." P.
934 12012 in *IOP Conference Series:*
935 *Earth and Environmental Science.* Vol.
936 270. IOP Publishing.

937 Dirpan, Andi. 2008. *ZECC (Zero Energy Cool*
938 *Chamber) Penyimpanan Dingin Yang*
939 *Murah Dan Ramah Lingkungan Untuk*
940 *Memperpanjang Masa Simpan Buah*
941 *Dan Sayur Setelah Panen.* Makassar:
942 Universitas Hasanuddin.

943 Dirpan, Andi, Muhammad Tahir Sapsal,
944 Abdul Kadir Muhammad, Mulyati M.
945 Tahir, and Rahimuddin. 2017.
946 "Evaluation of Temperature and Relative
947 Humidity on Two Types of Zero Energy
948 Cool Chamber (ZECC) in South
949 Sulawesi, Indonesia." *IOP Conference*
950 *Series: Earth and Environmental Science*
951 101:012028.

952 El-Zeftawi, B. M., L. Brohier, L. Dooley, F.
953 H. Goubran, R. Holmes, and B. Scott.
954 1988. "Some Maturity Indices for
955 Tamarillo and Pepino Fruits." *Journal of*
956 *Horticultural Science* 63(1):163–69.

957 Herawati, Heny. 2008. "Penentuan Umur
958 Simpan Pada Produk Pangan." *Jurnal*
959 *Litbang Pertanian* 27(4):124–30.

960 Islam, M. P. and T. Morimoto. 2015.
961 "ScienceDirect Evaluation of a New
962 Heat Transfer and Evaporative Design

- 963 for a Zero Energy Storage Structure.”
964 *Solar Energy* 118:469–84.
- 965 Islam, M. P., T. Morimoto, and K. Hatou.
966 2013. “Dynamic Optimization of inside
967 Temperature of Zero Energy Cool
968 Chamber for Storing Fruits and
969 Vegetables Using Neural Networks and
970 Genetic Algorithms.” *Computers and
971 Electronics in Agriculture* 95:98–107.
- 972 Johansyah, Afrazak and Endang Kusdiantini.
973 2014. “Pengaruh Plastik Pengemas Low
974 Density Polyethylene (LDPE), High
975 Density Polyethylene (HDPE) Dan
976 Polipropilen (PP) Terhadap Penundaan
977 Kematangan Buah Tomat (*Lycopersicon
978 Esculentum*. Mill).” *Anatomi Fisiologi*
979 22(1):46–57.
- 980 Khairi, Amalya Nurul, Affan Fajar Falah, and
981 Agung Putra Pamungkas. 2017.
982 “Analisis Mutu Pascapanen Melon
983 (Cucumis Melo L.) Kultivar Glamour
984 Sakata Selama Penyimpanan.”
985 *CHEMICA: Jurnal Teknik Kimia*
986 4(2):47–52.
- 987 Kusumiyati, Kusumiyati, Farida Farida,
988 Wawan Sutari, and Syariful Mubarak.
989 2018. “Kualitas Buah Mangga Selama
990 Penyimpanan Pada Keranjang Anyaman
991 Bambu Dengan Identifikasi Ruang
992 Warna L*, A* Dan B.” *Kultivasi*
993 17(2):628–32.
- 994 Masfufatun, Widaningsih, N. Kumala, and T.
995 Rahayuningsih. 2009. “Pengaruh Suhu
996 Dan Waktu Penyimpanan Terhadap
997 Vitamin c Dalam Jambu Biji (*Psidium
998 Guajava*).” *Universitas Wijaya Kusuma,
999 Surabaya*.
- 1000 Muchtadi, Deddy. 1992. *Fisiologi Pasca
1001 Panen Sayuran Dan Buah-Buahan:
1002 Petunjuk Laboratorium*. Institut
1003 Pertanian Bogor.
- 1004 Mulyati. 2012. *Sayur-Sayuran, Buah-Buahan
1005 Penanganan Dan Pengolahannya*.
1006 Makassar: CV. Indo media.
- 1007 Mulyawanti, Ira, Enrico Syaefullah, and Dwi
1008 Amiarsi. 2018. “Teknologi Pengemasan
1009 Atmosfir Termodifikasi (Modified
1010 Atmosphere Packaging/Map) Dan
1011 Vakum Pada Buah Durian.”
- 1012 Pantastico, E. B. 1986. *Fisiologi Pascapanen,
1013 Penanganan Dan Pemanfaatan Buah-*
- 1014 *Buahan Dan Sayur-Sayuran Tropika
1015 Dan Subtropika (Terjemahan
1016 Kamariyani 1997)*. Yogyakarta: Gajah
1017 Mada University Press.
- 1018 Park, T., Y. A. Kim, and J. Yun. 2004. “The
1019 Need for Collaboration in the Supply
1020 Chain For Successful Direct Shipments.”
1021 in *Proceedings of the Thirty-Third
1022 Annual Meeting of the Western Decision
1023 Sciences Institute*.
- 1024 Rawat, Seema. 2015. “Food Spoilage:
1025 Microorganisms and Their Prevention.”
1026 *Asian Journal of Plant Science and
1027 Research* 5(4):47–56.
- 1028 Retnani, Y., W. Widiarti, I. Amiroh, L.
1029 Herawati, and K. B. Satoto. 2009. “Daya
1030 Simpan Dan Palatabilitas Wafer Ransum
1031 Komplit Pucuk Dan Ampas Tebu Untuk
1032 Sapi Pedet.” *Media Peternakan*
1033 32(2):130–36.
- 1034 Rizkia. 2004. “Kajian Laju Respirasi Dan
1035 Perubahan Mutu Buah Mangga Gedong
1036 Gincu Selama Penyimpanan Dan
1037 Pematangan Buatan.” Institut Pertanian
1038 Bogor.
- 1039 Schwartz, Naomi. 2009. “Pengaruh Jenis
1040 Bahan Pengemas Terhadap Kualitas
1041 Cabe Merah Segar Selama Penyimpanan
1042 Dingin.” Universitas Sumatra Utara.
- 1043 Syafutri, Merynda I., F. Pratama, and D.
1044 Saputra. 2006. “Sifat Fisik Dan Kimia
1045 Buah Mangga (*Mangifera Indica* L.)
1046 Selama Penyimpanan Dengan Berbagai
1047 Metode Pengemasan.” *Jurnal Teknologi
1048 Dan Industri Pangan* 17(1):1–11.
- 1049 Tannenbaum. 1976. *Vitamins and Mineral*.
1050 New York (US: Merceel Dekker).
- 1051 Taqqiyah, Affifah. 2015. “Pengaruh
1052 Penambahan Fungisida Pada Bahan
1053 Pencuci Serta Suhu Penyimpanan
1054 Terhadap Peningkatan Kualitas Mangga.
1055 (*Mangifera Indica* L.)”
- 1056 Winarno. 2002. *Fisiologi Lepas Panen
1057 Produk Hortikultura*. Bogor: M-Brio
1058 Press.
- 1059

ram kishan <rkishan05@rediffmail.com> Sep 16, 2021, 5:41 PM

to me

Kindly submit Word file of your paper in single column along with its plagiarism report.
Thanks

Dr.Ram
Chief-Editor,IJASS

Kishan



Andi Dirpan <dirpan@unhas.ac.id> Sep 17, 2021, 2:00 PM

to ram

Dear Prof. Ram Kishan,

Thank you for your kind response. We have revised the paper by a single column. We also attach the plagiarism report without the name, affiliation, and references in order to get more high accuracy of the plagiarism report. Please note that We used Turnitin for checking the plagiarism report.

We appreciate your time and look forward to your response.

Best regards

Andi Dirpan

turnitin.docx

by

Submission date: 17-Sep-2021 12:31PM (UTC+0700)

Submission ID: 1650506422

File name: turnitin.docx (121.93K)

Word count: 5767

Character count: 31005

Extending of Mango (*Mangifera Indica* L.) Shelf Life with Combination of Zero Energy Cool Chamber (ZECC) Storage Technology, Washing and Packaging¹⁾

1

2

ABSTRACT

3 Mangoes suffer up to a 20%-50% shrinkage, loss, and quality damage as a result of improper harvest
4 and post-harvest handling, as well as poor storage conditions. The presence of a post-harvest
5 technology system of Zero Energy Cool Chamber (ZECC) storage combined with pre-handling
6 treatment (washing and packaging) is one method of minimizing damage and extending the shelf life
7 of mangoes. The purpose of this study was to determine the mango golek's quality and shelf life by
8 using ZECC in combination with washing and packaging. This study used a completely randomized
9 design (CRD) with factorial patterns, specifically factor A (storage type) and factor B (packaging and
10 without packaging). The study's observation parameters were divided into two stages, with stage 1
11 consisting of physical parameters and stage 2 consisting of chemical, microbiological, and sensory
12 parameters. According to preliminary research, the best treatment is washing with 1% detergent + 0.5
13 percent Ca(OH)_2 , which results in a smoother skin surface, less noticeable discoloration, and a cleaner
14 surface free of sap and dirt. Physical, chemical, microbiological, and sensory analysis of mango golek
15 (*Mangifera indica* L.) demonstrates that the ZECC storage technique can maintain fruit quality
16 optimally in combination with washing (chemical) and packaging treatment processes, and it can
17 effectively protect the mango golek's quality for up to 21 days.

18 **Keywords:** Mango, Quality, ZECC Storage

19

I. INTRODUCTION

20

1.1 Background

21

22 Indonesia possesses immense natural resource potential, particularly in horticultural crops like
23 mango. According to the Indonesian Central Statistics Agency, mango production reached 2,431,329
24 tons per year in 2014 and 2,178,833 tons per year in 2015, a decrease of 10.39 percent. Mango
25 productivity continues to be harmed by improper harvesting and post-harvest handling, which
26 degrades the quality of the mangoes. Additionally, storage conditions are insufficient during
27 agricultural product distribution and marketing, resulting in fruit depreciation. According to research
28 conducted in developing countries, improper harvesting and post-harvest handling can result in fruit
29 yield losses ranging from 20% to 50% (Dirpan et al. 2017)

30

31 Cold storage is one technique for postharvest handling. However, rural areas, which are
32 typically agricultural centers, have severe shortages of cold storage, such as refrigerators.
33 Additionally, the high operational costs associated with cold storage present a significant barrier to
34 farmers employing post-harvest handlers. Additionally, it produces freon, an environmentally
35 hazardous chemical (Dirpan et al. 2017). In light of the aforementioned issues, we require an energy-
36 free (zero energy) cold storage system that is also affordable (low cost) and environmentally friendly
37 (eco friendly), one of which is the Zero Energy Cool Chamber (ZECC) (Islam and Morimoto 2015).

38

39 The Zero Energy Cool Chamber (ZECC) is a cost-effective and environmentally friendly
40 method of storing fruits and vegetables following harvest. Due to the fact that ZECC does not require
41 electricity to operate, it is frequently referred to as an environmentally friendly fruit and vegetable
42 storage system (Dirpan 2019; Islam, Morimoto, and Hatou 2013) Additionally, this storage system is
43 cost effective due to the fact that it makes use of readily available materials such as bricks, sand,
44 plastic roofs, and water (Dirpan et al. 2017; Islam et al. 2013)

45

46 Recent years have seen an increase in research on fruit and vegetable storage methods utilizing
47 ZECC, as demonstrated by Kamilia et al. (2017) and Dirpan et al. (2018) studies examining the
48 quality of mangoes and tomatoes stored in ZECC (Ali 2017; Dirpan 2008). However, because fungi
49 grew around the mangoes in the aforementioned studies, ZECC was used in conjunction with pre-
50 handling treatments such as washing and packaging to minimize the possibility of mold and yeast
51 growth and to extend the shelf life of the golek mango. As a result, the purpose of this research were:
52 to determine the physical, chemical, microbiological, and sensory characteristics of mango golek
53 stored in a ZECC (Zero Energy Cool Chamber) in combination with washing and packaging

50 processes and to determine the shelf life of mangoes stored in a ZECC (Zero Energy Cool Chamber)
51 in combination with washing and packaging processes.

52 II. Materials and Methods

53

54 II.1 Date and Location of Research

55 This research was conducted from July to November 2019 at the Food Processing Laboratory
56 and the Chemical Laboratory of Food Quality Analysis and Supervision of the Food Science and
57 Technology Study Program, Department of Agricultural Technology, Faculty of Agriculture,
58 Hasanuddin University, as well as at the Research Activity Center (PKP) building and Lecturer
59 Housing Unhas Tamanlarea, Makassar.

60 II.2 Instruments and materials

61 The tools used in this research include a zero energy cool chamber (ZECC), polypropylene
62 plastic packaging, fruit racks, temperature and relative humidity sensors, hoses, scales, analytical
63 scales, and moisture, analyzer, colorimeter, penetrometer, digital hand refractometer, pH meter,
64 stirring rod, beaker, erlenmeyer flask, volumetric flask, dropper pipette, volume pipette, petri dish,
65 autoclave, bulb, micropipet, test tube, tube rack, laminar air flow (LAF), plates, spoons, knives, rags,
66 blenders.

67 Materials used in this study were 77 golek mango (main ingredient) with a maturity index of 2
68 (light green), aquadest, detergent, chlorine, calcium hydroxide ($\text{Ca}(\text{OH})_2$), sodium hydroxide
69 (NaOH), iodine, indicator phenolphthalein, alcohol, buffer pH 7, mineral water, starch indicator
70 (starch), potato dextrose agar (PDA) medium, inhibitor (chloramphenicol), cotton, and labels.

71 II.3 Research procedure

72 The research process is as follows:

73 II.3.1 Preliminary research

74 Mangoes are sorted, and then those that are not rotten or injured are selected for this research.
75 The mango is then graded according to its maturity level. Following that, the Zero Energy Cool
76 Chamber (ZECC) is chemically sterilized by spraying 0.5 percent chlorine + 70% alcohol. After that,
77 the mangoes are prepared and washed using water, detergent, and $\text{Ca}(\text{OH})_2$ in accordance with the
78 treatment method. After washing, Mangoes were air-dried and then stored in two different conditions:
79 ZECC and room temperature.

80 After that, the mango fruit was observed daily for changes until the eighth day of storage.

81 II.3.2 Main research

82 The following stage is mango that has received the best treatment during the washing process
83 (1 percent detergent + 0.5 percent $\text{Ca}(\text{OH})_2$), combined with post-harvest technology, specifically
84 packaging techniques utilizing Polypropylene (PP) plastic, and then returned to the sterilized ZECC.
85 Each day, the fruit is analyzed for damage, which is defined as shriveling, softening, dull skin color,
86 the appearance of black spots on the fruit's skin, and the presence of mold at the fruit's base.

87 II.4 Research design

88 The design of the research is divided into two stages. The first stage is to determine the optimal
89 treatment for washing mangoes using various washing ingredients, with the following treatments:

90 A₀ : Control (Without washing)

91 A₁ : Water-based cleaning

92 A₂ : 0.5% detergent + 0.25 % $\text{Ca}(\text{OH})_2$

93 A₃ : 1% detergent + 0.5% $\text{Ca}(\text{OH})_2$

94 Following with storage in ZECC and at room temperature, Physical parameters of the fruit skin
95 surface, color, sap, and impurities were observed visually.

96 The next step is, mango that received the best treatment during the washing process, combined
97 with packaging techniques utilizing Polypropylene (PP) plastic. It is then analyzed every three days
98 using a variety of observation parameters

99

100 II.5 Data analysis

101 The data obtained in the second phase of the study were compiled using a completely
102 randomized design (CRD) with a factorial pattern, namely factor A (type of storage) and factor B
103 (packaged and unpackaged). The research was carried out with three replications.

104 Data processing used quantitative descriptive method, all parameters were analyzed by analysis
105 of variance (ANOVA) with three replications. The differences for each treatment were further tested
106 using Duncan's test. The software used for data processing is Microsoft Excel 2016 and IBM SPSS
107 Statistics Version 23.

108 **II.6 Observation Parameter**

109 Observation parameters in stage 1 are physical parameters of fruit skin surface, color, sap and
110 dirt. Parameters observed in stage 2 include vitamin C, pH value, water content, total acid, total
111 dissolved solids, weight loss, skin color, hardness test, total microbe, and organoleptic test using 15
112 panelists.

113

114 **III. RESULT AND DISCUSSION**

115

116 **III.1 First Phase of Research**

117 The results of the storage of mangoes from the preliminary study showed that mangoes stored
118 at ZECC had better physical quality (visually) than mangoes stored at room temperature. Mangoes
119 stored in ZECC had smoother skin, less noticeable skin discoloration until the 8th day of storage,
120 fewer lenticel spots, and did not grow fungus on the skin surface. The fruit that was stored at room
121 temperature with a rougher skin surface (wrinkled), slightly noticeable skin discoloration, lenticel
122 spots began to appear on the 5th day of storage, as well as fungal growth in some mango samples.
123 These results indicate that storage using the ZECC method is good for extending the shelf life of
124 mangoes compared to storage at room temperature.

125 **III.1.1 Mango Skin Surface**

126 Visual observations of the mango skin's surface revealed that ZECC storage was better
127 compared to room temperature storage. Mango fruits stored in ZECC had smoother skin (not
128 wrinkled) than mango fruits stored at room temperature, which had wrinkled skin surface. The
129 absence of wrinkles in mangoes stored at ZECC is due to the relative humidity (RH) in a good storage
130 room, which is between 80% and 98.04 percent, as opposed to room temperature, which has a relative
131 humidity of 50% to 56.90 percent. This is consistent with Muchtadi (1992) who states that all
132 varieties of mango are susceptible to cold damage in the form of dark spots, uneven ripening, and
133 failure to produce adequate flavor and color, and that a relative humidity of 85-90 percent is required
134 to prevent wilting and softening of various fruits and vegetables (Muchtadi 1992).

135 The room temperature is higher than the temperature in the ZECC. ZECC has a temperature
136 range of 24-25°C, while the ambient temperature ranges from 26-31°C. Mango fruit stored at room
137 temperature transpired and respired at a faster rate than mango stored in ZECC, causing the mango
138 skin to wrinkle. Because respiration rate is related to the rate of quality deterioration, it can be used
139 to estimate the shelf life of fruit after harvest. As stated by Rizkia (2004) that the slower the rate of
140 respiration, the longer the fruit can be stored in its fresh state; conversely, the faster the rate of
141 respiration, the shorter the shelf life (Rizkia 2004).

142 **III.1.2 Skin color**

143 Mangoes are generally observed visually by observing how clearly the color change from green
144 to yellow appears on the mango skin. Mangoes stored at room temperature and in ZECC without
145 treatment/washing (control), as well as those washed with water and detergent + Ca(OH)₂ exhibited
146 no discernible color changes. On the sixth day of observation, the color changed to a slight yellow
147 hue. This color change occurs because mangoes, as climacteric fruits, accelerate the ripening process
148 during storage. The maturation process that occurs concurrently with the breakdown of chlorophyll,
149 resulting in the appearance of other color pigments such as yellow and red, causing the green color
150 to degrade. This is in line with El-Zeftawi *et al.*, (1988), who stated that the level of chlorophyll

151 content in green fruit decreases during the storage, other pigments begin to appear, turning the fruit
152 yellow or orange (El-Zeftawi et al. 1988).

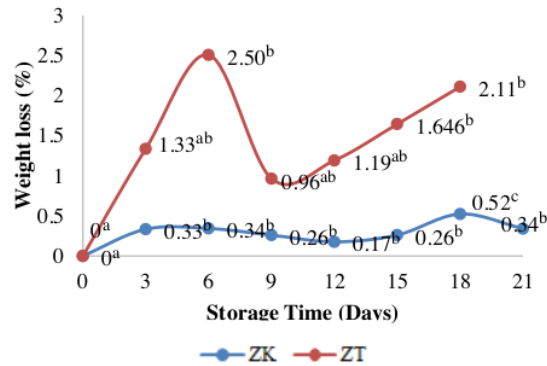
153 III.1.3 Sap and Dirt

154 For mango fruit washed with water, on day 6 DAW (day after washing), there were still
155 remnants of sap attached to the surface of the mango fruit skin, although they were not particularly
156 noticeable. However, there were a few lenticel spots and a change in color at the fruit base on day 6
157 DAW (day after washing) until the 8th day of DAW. While mangoes treated with 1% detergent +
158 0.25 percent $\text{Ca}(\text{OH})_2$ can visually remove sap, the treatment was more effective at 1% + $\text{Ca}(\text{OH})_2$
159 0.5 percent detergent immersion, which resulted in samples of mango fruit being more free of sap
160 and dirt, resulting in a smoother surface with no noticeable changes up to 8 DAW. This is because
161 1% detergent binds to oil and effectively removes or lifts dirt. Until the eighth day after DAW mango
162 was treated with 1% detergent and 0.5 percent $\text{Ca}(\text{OH})_2$, no lenticel or fungal spots appeared at the
163 base or on the surface of the fruit skin. The surface is smoother and burn-free because the detergent's
164 surfactant active ingredients can remove the oil contained in the sap. Alkaline $\text{Ca}(\text{OH})_2$ solution can
165 neutralize the acid in the sap attached to the golek mango cultivar's skin. This is consistent with
166 Ahmad, S et al (2017)'s finding that the 1% + $\text{Ca}(\text{OH})_2$ 0.5 percent detergent treatment resulted in a
167 lower mean score for reducing lenticel spots at 2 to 14 DAW when compared to the control (Ahmad
168 et al. 2017). In accordance with Taqiyah (2015), a combination of detergent and $\text{Ca}(\text{OH})_2$ is capable
169 of removing sap and oil from the surface of the Gedong mango skin (Taqiyah 2015).

170 III.2 Second Phase of Research

171 The second stage of this study involved determining the quality and shelf life of mangoes while
172 they were stored. Mangoes that received the best washing treatment (1 percent detergent + 0.5 percent
173 $\text{Ca}(\text{OH})_2$) were then given packaging treatment (using Polypropylene (PP) plastic and without
174 packaging) and then analyzed for quality. Mangoes packaged with Polypropylene (PP) plastic can be
175 stored in ZECC for 21 days, whereas mangoes packaged without Polypropylene plastic have a shelf
176 life of only 18 days.

177 III.2.1 Weight Loss



178 Figure 1. The weight loss of Mangoes During Storage. Values followed by different letters indicate treatment results that are
179 significantly different ($p < 0.05$).
180

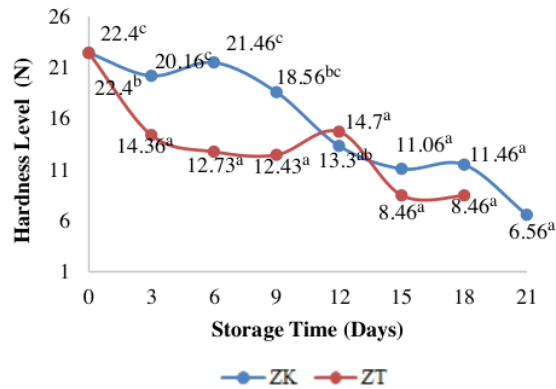
181 During storage, the mango fruit's weight loss tends to increase. Unpackaged mangoes (ZT) lost
182 approximately twice as much weight as packaged mangoes (ZK). This means that when packaging is
183 used in combination with the ZECC storage technique, mangoes lose less weight. Unpackaged
184 mangoes experienced a greater increase in weight loss due to a high evaporation rate (transpiration),
185 whereas packaged mangoes experienced less water evaporation during storage. Water loss results in
186 withering and shrinking. This is consistent with Winarno (2002), who states that the amount of water
187 in foods determines their freshness, appearance, and durability (Winarno 2002). If some of the water
188 in the food evaporates, weight loss occurs, reducing the food's freshness, appearance, and durability.

189 In addition to transpiration, weight loss is also influenced by the respiration process of mango
190 fruit. Carbon loss can occur during the respiration process. Carbon compounds contained in the sugar
191 in mangoes will bind and react with oxygen which will produce simple volatile compounds, namely

192 water vapor and carbon dioxide so that the fruit will lose its weight. So in this case it is known that
193 the respiration process can be suppressed by a combination of packaging and storage in ZECC. This
194 is in accordance with the opinion of Syafutri et al., (2006), which states that the process of fruit
195 respiration can be suppressed by combining packaging and storage at low temperatures (Syafutri,
196 Pratama, and Saputra 2006).

197
198
199
200

201 III.2.2 Hardness Level



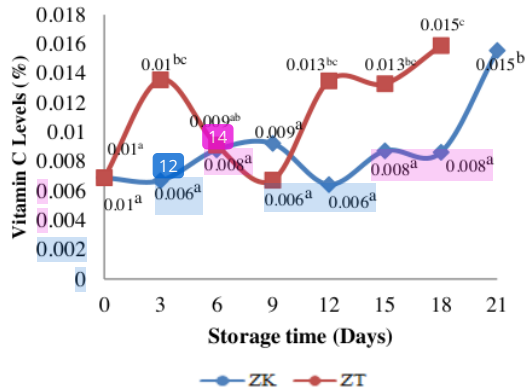
202
203
204

Figure 2. The Hardness Level of Mango Fruit During Storage. Values followed by different letters indicate treatment results that are significantly different ($p < 0.05$).

205 The ripening process of mangoes during storage results in changes in the level of mango fruit
206 hardness. The ripening process in mangoes occurs concurrently with the conversion or degradation
207 of protopectin to pectin, resulting in a decrease in cell wall rigidity. Mangoes without packaging
208 treatment (ZT) had a greater loss of hardness than mangoes with packaged treatment (ZK). This is
209 due to the fact that unpackaged mangoes have a higher respiration rate and a higher enzyme activity.
210 The more actively these enzymes are, the softer the texture of the fruit. Meanwhile, the rapid rate of
211 respiration causes the fruit tissue to rupture, resulting in the mango becoming soft. The mango with
212 packaging treatment (ZK) can reduce the amount of oxygen received, thereby slowing the respiration
213 process (maintained). This is consistent with Syafutri et al. (2006), who state that the decrease in
214 hardness is also a result of the respiration and transpiration processes (Syafutri et al. 2006). The
215 respiration process results in the breakdown of carbohydrates into simple compounds and tissue
216 rupture, resulting in the mango becoming soft, whereas the transpiration process results in water
217 evaporation, resulting in the mango becoming wilted.

218
219
220
221
222
223
224
225
226

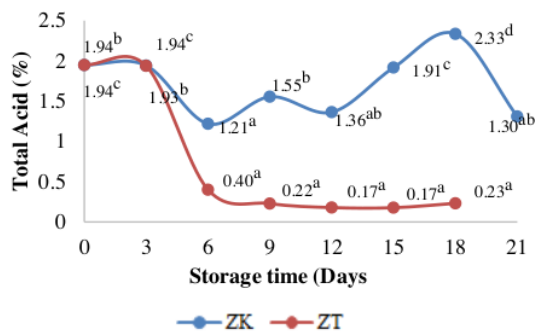
227 III.2.3 Vitamin C levels



228 Figure 3. Vitamin C Levels of Mangoes During Storage. Values followed by different letters indicate treatment results that are
 229 significantly different ($p < 0.05$).
 230

231 The levels of vitamin C (ascorbic acid) of mangoes during storage in ZECC tend to vary, both
 232 packaged in polypropylene plastic and mangoes without packaging. The significant increase in
 233 vitamin C levels of unpackaged mangoes until the end of storage was in line with the faster ripening
 234 process of mangoes compared to packaged mangoes. This is in accordance with Pantastico (1986),
 235 which states that ripe fruit will increase in acidity, and this increase occurs simultaneously with the
 236 climacteric pattern, while vitamin C levels will decrease when the maximum point of increase has
 237 been exceeded (withering stage) (Pantastico 1986). The ripening process of unpackaged mangoes is
 238 faster because the respiration process is greater than that of packaged mangoes. Mango packaging
 239 can regulate minimize the respiration process of the fruit so that the freshness of the mango can be
 240 maintained. This is in accordance with Park et al., (2004), which states that Polypropylene (PP) plastic
 241 has high permeability properties which can regulate the rate of atmospheric absorption or respiration
 242 rate which can maintain fruit freshness longer (Park, Kim, and Yun 2004). The results of analysis of
 243 variance showed that mango without packaging treatment and mango with packaging treatment had
 244 a significant effect on vitamin C levels during storage. This is indicated by the value of vitamin C
 245 which was initially low and then increased until the end of storage. The increase or decrease in vitamin
 246 C is because the vitamin is unstable, easily oxidized when exposed to air (oxygen) and this process
 247 can be accelerated by storage temperature. This is in accordance with Tannenbaum (1976), stating
 248 that the reduction of O_2 will inhibit the degradation of ascorbate into dehydroascorbic acid and H_2O_2
 249 (Tannenbaum 1976). The resulting H_2O_2 will cause autoxidation so that it will increase the damage
 250 of vitamin C.

251 III.2.4 Total Acid



252 Figure 4. Total Acid Level of Mango Fruit During Storage. Values followed by different letters indicate treatment results that are
 253 significantly different ($p < 0.05$).
 254

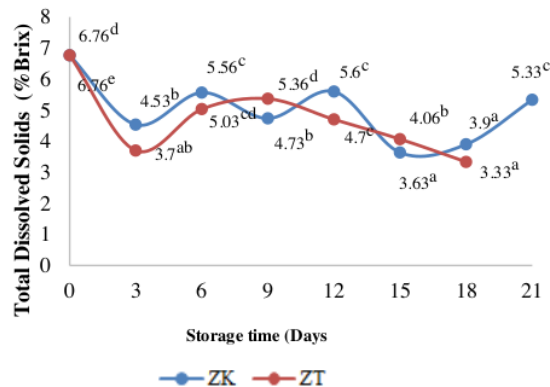
255 The total acid value of mango in ZECC storage, both packaged and unpackaged, tends to
 256 decrease, though the trend is variable. The percentage of total acid in the fruit decreases as the fruit
 257 is stored. The decrease in the percentage of total acid is due to the respiration process's use of organic
 258 acids, as well as the use of organic acids by microbes in energy-consuming activities. This energy is

259 obtained through the breakdown of the nutrients found in food. Organic acids are converted to sugars
 260 during the respiration process. Amalya et al. (2017) found in their research that the fruit's decreased
 261 organic acid value indicated that the fruit's ripening metabolism was functioning normally (Khairi,
 262 Falah, and Pamungkas 2017).

263 Total acid in mangoes that were not packaged (ZK) contained a greater proportion of total acid
 264 or degraded more rapidly than in packaged mangoes (ZK). This is due to the respiration process of
 265 unpackaged mangoes. Merynda et al. (2006) state that when mangoes are not packaged, the
 266 respiration process cannot be minimized due to the abundant O₂ in the environment (Syafutri et al.
 267 2006).

268 III.2.5 Total Dissolved Solids (TDS)

269 Mangoes' total dissolved solids (packaged and unpackaged) exhibit a fluctuating graph.
 270 Unpackaged mangoes (ZT) underwent a maximum ripening process, as indicated by the percentage
 271 of TDS value increasing significantly at first and then gradually decreasing until the end of storage.
 272 The increase in TDS is a result of starch hydrolysis during ripening process. While the decrease in
 273 TDS occurs as a result of the abundant O₂ available in the environment, which prevents the respiration
 274 process from being suppressed. Thus, glucose as the result of starch hydrolysis then was consumed
 275 during the respiration process, resulting in a rapid decrease in the sugar content of the fruit. Pantastico
 276 (1993) confirms this by stating that during ripening, starch is hydrolyzed into simple compounds that
 277 serve as a source of energy during the respiration process (Pantastico 1986). At this point, the sucrose
 278 has been converted back to glucose and fructose. The decrease in total sugar content of unpackaged
 279 mangoes occurred as the mango fruit began to ripen, at which point the starch content began to
 280 decrease and the activity of the invertase enzyme decreased, resulting in a decrease in sugar content.
 281 The mango with packaging (ZK) has the ability to maintain the fruit's ripening process, as indicated
 282 by the predominant fluctuating TDS value. This demonstrates that by combining packaging and
 283 storage in ZECC, the rate of decrease in the percentage of TPT in mangoes can be slowed.



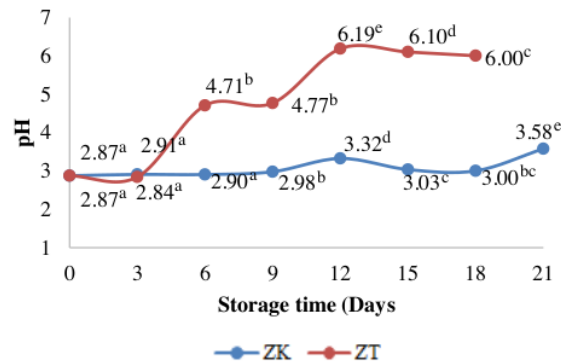
284 Figure 5. Total Dissolved Solids of Mango Fruit During Storage. Values followed by different letters indicate treatment results that are
 285 significantly different (p<0.05).
 286

287 This variable total dissolved solids value is also a result of the fruit's non-uniform maturity
 288 level. Non-uniform fruit ripeness causes abnormal respiratory activity so that the breakdown process
 289 of simple sugars varies. In general, changes in total dissolved solids content increased at the maximum
 290 point of storage and then decreased until the fruit began to rot on the final day of storage. This is
 291 consistent with Biale and Young's (1971) observation that the general trend is for a rapid increase in
 292 sugar content followed by a decline; in climacteric fruit, this condition becomes a marker (Biale and
 293 Young 1971).

294 III.2.6 Degree of Acidity (pH)

295 According to the graph, mango fruit are acidic, with a pH value ranging between 2 and 6 during
 296 storage. The ripening of mangoes alters the pH value of the fruit. Without packaging treatment (ZT),
 297 mango matured rapidly (maximum), increasing the pH value. It is not the case with packaged
 298 mangoes (ZK), as their ripening process is slowed, resulting in a stable pH value throughout storage.
 299 As the mango ripens, the acid content decreases while the simple sugars increase, as indicated by the

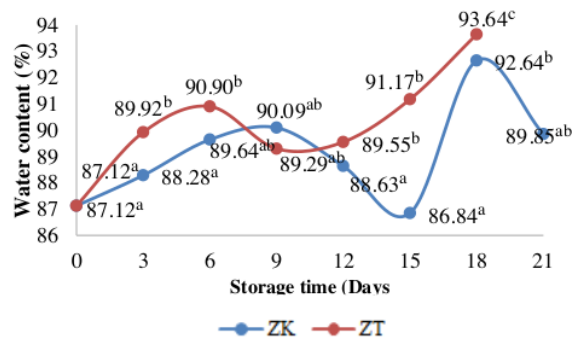
300 decrease in total acid content. The pH value is directly proportional to vitamin C levels and inversely
 301 proportional to total acidity, as shown in the graph. This is consistent with Amalya et al., (2017), who
 302 state that changes in pH indicate changes in the composition of the fruit's cell fluid as it matures; the
 303 pH value that tends to be high is related to relatively high ascorbic acid (vitamin C) levels during
 304 storage; this change indicates that the fruit's metabolism affects the pH value (Khairi et al. 2017).



305
 306 Figure 6. pH Value (Degree of Acidity) Mango Fruit During Storage. Values followed by different letters indicate treatment results
 307 that are significantly different ($p < 0.05$).

308 III.2.7 Water content

309 The water content of mangoes stored in the ZECC method varied slightly during storage. When
 310 compared to unpackaged mangoes, packaged mangoes (ZK) are able to maintain changes in water
 311 content during storage. This is because PP packaged mangoes have a high permeability, which
 312 minimizes changes in water content during storage. This is consistent with Schwartz (2009), who
 313 states that because of the packaging, ambient air cannot easily enter the material, thereby inhibiting
 314 the process of water exchange during storage (Schwartz 2009).



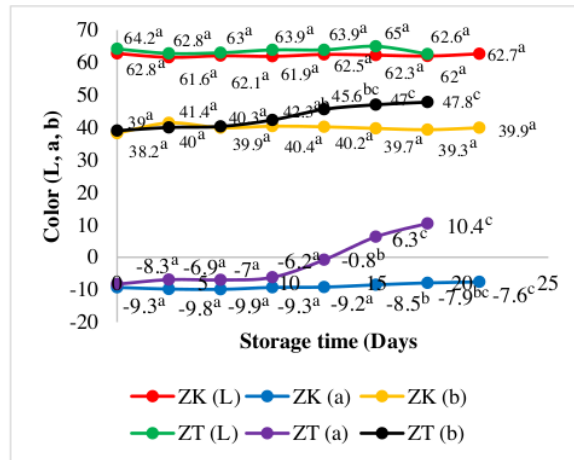
315
 316 Figure 7. Water Content of Mangoes During Storage. Values followed by different letters indicate treatment results that are significantly
 317 different ($p < 0.05$).

318 Due to the high humidity in ZECC storage, which reached 80-90 percent, mango fruit
 319 experienced an increase and decrease in water content during storage. Due to the high humidity level
 320 in the ZECC room, moisture absorption from the environment into the stored mango is possible. The
 321 longer the storage time, the higher the water content will remain. According to Herawati (2008), a
 322 significant factor influencing the decline in the quality of food products is changes in the product's
 323 water content, which can be influenced by the room's temperature and humidity during storage
 324 (Herawati 2008). This opinion is backed up by Retnani et al., (2009), who state that the high humidity
 325 of the storage room can result in the absorption of water vapor from the air into the foodstuffs,
 326 resulting in an increase in water content (Retnani et al. 2009).

327 Additionally, the increase in water content during storage is a result of the mangoes' respiration
 328 process. During storage, the fruit undergoes a ripening process that includes the conversion of starch
 329 to simple sugars ($C_6H_{12}O_6$). These simple sugars then interact with the oxygen (O_2) in the chamber,
 330 increasing the rate of water (H_2O) formation in the fruit. This is consistent with Nurhayati S (2004),

331 who states that one of the causes of changes in the water content of fruit is the respiration process,
 332 during which water is formed as a result of sugar reorganization into simpler compounds.

333 **III.2.8 Color**



334 Figure 8. Analysis of Mango Skin Color During Storage. Values followed by different letters indicate treatment results that are
 335 significantly different ($p < 0.05$).
 336

337 The L^* value indicates the brightness level of the mango fruit, which indicates the reflected
 338 light that produces achromatic colors of white, gray and black, ie from a value of 0 (black) – 100
 339 (white). The L^* value of unpackaged and packaged mangoes had a very small decrease in lightness
 340 value during storage. The range of changes in the L^* value from 65-62 indicates a slight decrease in
 341 brightness level during storage. The longer the fruit is stored, the lower the brightness level of the
 342 mango. According to Ahmad et al., (2014), that the brightness level of the color will decrease which
 343 will be directly proportional to the longer the shelf life, the fruit will lead to spoilage in the end
 344 (Ahmad, Darmawati, and Refilia 2014). The decreasing brightness level of the mango skin color is
 345 caused by changes in the chlorophyll content of the fruit. This is in accordance with the statement of
 346 Syafutri et al., (2006), which states that the reduced level of color brightness in fruit during storage
 347 is caused by reduced chlorophyll content in fruit skins and the appearance of carotenoids (Syafutri et
 348 al. 2006).

349 The a^* value is a value that shows the gradation of green to red. A mixed red-green chromatic
 350 color with a value of $+a^*$ (positive) from 0 to +80 for red and a value of $-a^*$ (negative) from 0 to -80
 351 for green. The a^* value of mango tends to increase during the storage process. Mangoes tend to be
 352 green, indicated by an a^* value below 0, but the longer the storage time, the color of the fruit moves
 353 to red. The significant increase in a^* value was caused by the high respiration rate of unpackaged
 354 mangoes so that the degradation of chlorophyll was also rapid which had the effect of accelerating
 355 the synthesis of pigment (color change) of the fruit. This is in accordance with the opinion of
 356 Masfufatun et al. (2015), which states that a high respiration rate will also cause chlorophyll
 357 degradation and pigment synthesis to be fast, consequently accelerating color changes (Masfufatun,
 358 Kumala, and Rahayuningsih 2009).

359 The b^* value indicates the color gradation to yellow. A mixed blue-yellow chromatic color
 360 with a $+b^*$ (positive) value from 0 to +70 for yellow and a $-b^*$ (negative) value from 0 to -70 for
 361 blue. Based on the graph above, it shows that unpackaged mangoes have a slowly increasing b^* value
 362 during storage compared to packaged mangoes whose b^* values tend to be stable until the end of
 363 storage. The results of the measurement of the b^* value show that the longer the storage, the yellow
 364 color of the mango will be clearer. The increasing b^* value in unpackaged mangoes indicates that the
 365 fruit is getting more mature than the packaged mangoes during storage. This is in accordance with
 366 the statement of Kusumiyati et al., (2018), which states that the longer the storage, the yellow color
 367 of the mango is more clearly marked by the higher the mean b^* value. The higher the b^* value in the
 368 mango can be indicated the higher the ripeness level of the fruit (Kusumiyati et al. 2018).

369

370

371 III.2.9 Organoleptic test

372 III.2.9.1 Color

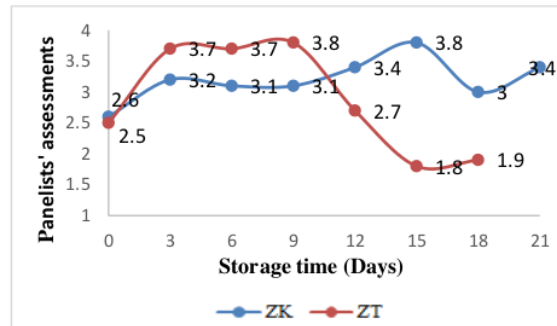


Figure 9. Results of Organoleptic Testing on Mango Color in ZECC Storage

373
374

375 The changes in panelists' assessments of organoleptic color parameters in mangoes were due to
376 the nature of mangoes undergoing post-harvest ripening (after harvesting), specifically that the color
377 will change during the storage process due to chlorophyll degradation into other pigments. The
378 panelists' assessment of mangoes with packaging treatment (ZK) tended to remain stable until the end
379 of storage, with an average value of 3 (slightly similar), whereas mangoes without packaging (ZT)
380 maintained an average value of 4 (similar) until the ninth day of storage, when it decreased until the
381 end of storage. This demonstrates that mangoes treated with packaging can help preserve or delay the
382 color change of mangoes stored in ZECC. Packaging treatment on mangoes can slow the respiration
383 process, resulting in a slower color change and maturation and aging process. This is consistent with
384 Kamilia (2017), who states that a faster respiration rate can accelerate the senescence process, which
385 results in a more rapid color change.

386 III.2.9.2 Aroma

387 The panelists' evaluations of the mango aroma parameters revealed a range of results but a
388 consistent pattern of increasing and then decreasing until the end of storage. In terms of fruit aroma,
389 panelists prefer the unpackaged aroma of mango fruit.

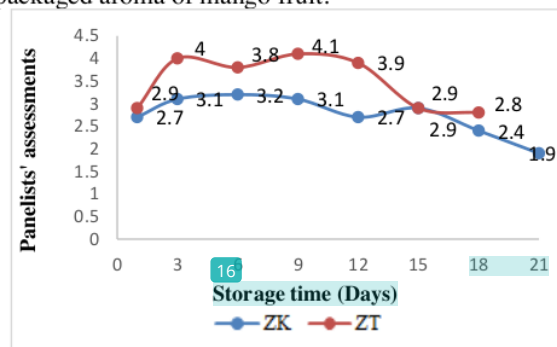
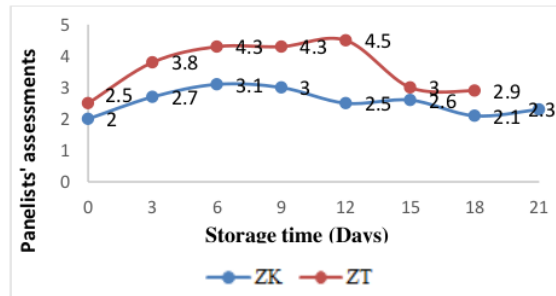


Figure 10. Results of Organoleptic Testing on Mango Aroma in ZECC Storage

390
391

392 The high acceptance of unpackaged mango aroma (ZT) is a result of the increasing ripening
393 process (perfect ripening), which results in an increase in the production of volatile components.
394 While the packaged mango (ZK) took longer to decompose, the panelists generally disliked it due to
395 the incomplete ripening process, which resulted in a low flavor. This is consistent with Muchtadi
396 (1992), who stated that ripening typically results in an increase in the content of simple sugars, which
397 imparts a sweet flavor, as well as an increase in the production of volatile substances, which imparts
398 a distinctive fruit flavor.

399 III.2.9.3 Taste



Gambar 11. Results of Organoleptic Testing on Mango Taste in ZECC Storage

400
401

402 The results of organoleptic tests on mangoes stored at ZECC showed that the panelists'
403 assessment of fruit taste increased and then decreased until the end of storage. The range of values
404 between 3-5 (based on the graph) shows that the panelists' assessment of unpackaged mangoes (ZT)
405 is dominantly preferable to mangoes with packaged treatment (ZK) with a value of 2-3. The high
406 rating for unpackaged mangoes is because the mangoes undergo an even ripening process during
407 storage, resulting in a distinctive taste and good color which are preferred by panelists (Ali 2017).
408 The sweet taste is due to the change in the starch content of the fruit to sugar during storage. This is
409 in accordance with the statement of Mulyati (2012), that changes during the ripening process are
410 changes in starch and fat reserve materials into various sugars (Mulyati 2012). The mango with
411 packaging (ZK) undergoes a slow ripening process due to its low respiration rate in the presence of
412 packaging, but it takes longer to decay or damage in ZECC storage.

413

414 **IV.2.9.4 Texture**

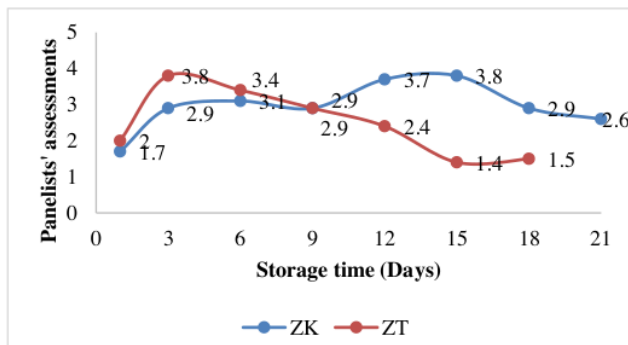


Figure 12. Results of Organoleptic Testing on Mango Texture in ZECC Storage

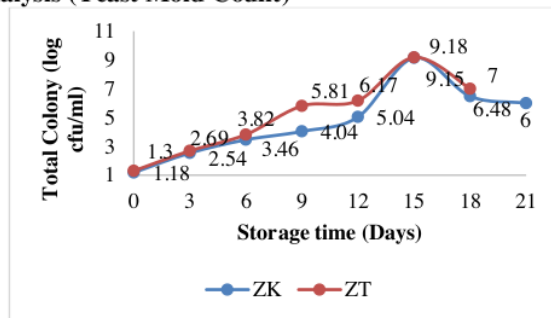
415
416

417 Panelists determined that mango with packaged treatment (ZK) (mean value 3-4) was preferable
418 in terms of texture because the level of hardness did not decrease significantly (soft), as opposed to
419 mango without packaged treatment (ZT) (mean value 2-3). The texture began as hard, which the
420 panelists disliked, then softened slightly, which the panelists liked, and finally became extremely soft
421 due to damage/rotting, which the panelists disliked. When the qualitative (organoleptic test of texture
422 parameters) analysis of mango fruit is combined with quantitative analysis (with a penetrometer), it
423 is discovered that the level of hardness (the process of hardness decreasing) is directly proportional
424 during storage.

425 Mangoes' softening texture is caused by the ripening process that occurs during storage.
426 Maturation occurs concurrently with the conversion or degradation of insoluble protopectin to soluble
427 pectin. The reshuffle occurs as a result of the action of enzymes such as pectin methyl esterase, which
428 softens the fruit. Proteopectin levels in the fruit decrease as the fruit ripens, while pectin levels
429 increase. This is in accordance with Afrazak et al., (2014), that as fruit ripens and stores, some of the
430 water-insoluble protopectin converts to water-soluble pectin, reducing the cohesion of the cell walls
431 that connect cells, resulting in a decrease in texture or fruit hardness and the fruit becoming soft
432 (Johansyah and Kusdiantini 2014). Additionally, the rate of respiration has an effect on the degree of
433 hardness or texture. Unpackaged mangoes with a high respiration rate cause the fruit's tissue to

434 rupture and enzyme activity to accelerate, resulting in a softer fruit texture. The mango with
435 packaging treatment (ZK) can reduce the amount of oxygen received, thereby slowing the respiration
436 process (maintained).

437 **III.2.10 Microbial Analysis (Yeast Mold Count)**



438 Figure 13. Mold and Yeast cell count on Mangoes During Storage in ZECC
439

440 According to the graph, the results of microbial analysis (mold and yeast counts) on mango
441 fruit storage in ZECC indicated that yeast mold growth continued to increase and then decreased
442 gradually until the end of storage. Microbial growth (mold and yeast) that began low/small and then
443 increased to a maximum growth peak on the 15th day generally indicated that the mangoes' quality
444 deteriorated during storage and gradually entered the senescence phase. This also demonstrates that
445 mangoes with a relatively high sugar content and a low pH provide an ideal environment for molds
446 and yeasts to grow to their maximum growth capacity during storage. This is consistent with Seema
447 R (2015) statement that fruit with a high sugar content and a low/acidic pH (pH range between 3-8)
448 promotes the growth of fungi (mold/yeast) after the fruit is harvested (Rawat 2015).

449 Mango without packaging (ZT) exhibited a greater increase in the growth of the dominant
450 mold/yeast than mango with packaging (ZK). This demonstrates that by combining calcium
451 hydroxide washing with packaging on mangoes stored in ZECC, the rate of microbial growth can be
452 slowed or suppressed, thereby extending the fruit's life phase. Certain microbes require oxygen to
453 grow, which can be suppressed through packaging. This is consistent with the opinion of Ira M et al.
454 (2017), who state that treating fruit with packaging technology can suppress the air activity required
455 by microbes, thereby slowing the growth rate of pathogenic microbes (Mulyawanti, Syaefullah, and
456 Amiarsi 2018)

457

458

459

IV. Conclusions

460

461 It can be concluded that analysis of the quality of golek mango (*Mangifera indica* L.)
462 physically, chemically, microbiologically, and sensory in the Zero Energy Cool Chamber (ZECC)
463 storage technique shows that ZECC can maintain optimal fruit quality through a washing treatment
464 process (chemically) in combination with packaging. In addition, the Zero Energy Cool Chamber
465 (ZECC) storage method with a combination of washing and packaging treatments is effective in
466 maintaining the quality of mangoes up to 21 days of storage.

467

ORIGINALITY REPORT

9%

SIMILARITY INDEX

2%

INTERNET SOURCES

7%

PUBLICATIONS

4%

STUDENT PAPERS

PRIMARY SOURCES

1

Submitted to Universitas Hasanuddin

Student Paper

3%

2

Andi Dirpan, Muhammad Tahir Sapsal, Mulyati M Tahir, Muspirah Djalal, Ashabul Firdaus. "The potential of the ZECC–washing combination to extending the mango's shelf life", IOP Conference Series: Earth and Environmental Science, 2020

Publication

2%

3

A Dirpan. " The Quality of Tomato .) Stored on ZECC (Zero Energy Cool Chamber) ", IOP Conference Series: Earth and Environmental Science, 2019

Publication

<1%

4

spotidoc.com

Internet Source

<1%

5

M Sonangda, H Sinaga, L N Limbong. " Effect of ratio of andaliman with garlic and aging time on the quality of sambal tuk tuk ", IOP Conference Series: Earth and Environmental Science, 2019

<1%

| | | |
|----|---|------|
| 6 | N A Arshimny, K Syamsu. " Production and characteristic of natural coloring and flavoring preparations from pandan leaves () ", IOP Conference Series: Earth and Environmental Science, 2020 Publication | <1 % |
| 7 | M K Nisa, E Prihastanti, S Haryanti. " The Effect of plasma radiation with leaf fertilizer combination on vegetative growth of orchid planlets sp. at the acclimatization stage ", Journal of Physics: Conference Series, 2019 Publication | <1 % |
| 8 | agritech.unhas.ac.id Internet Source | <1 % |
| 9 | mafiadoc.com Internet Source | <1 % |
| 10 | Sram, R.J.. "Vitamin C for DNA damage prevention", Mutation Research - Fundamental and Molecular Mechanisms of Mutagenesis, 20120501 Publication | <1 % |
| 11 | d.researchbib.com Internet Source | <1 % |
| 12 | dx.doi.org Internet Source | <1 % |

13

A Dirpan, R Latief, A Syarifuddin, A N F Rahman, R P Putra, S H Hidayat. " The use of colour indicator as a smart packaging system for evaluating mangoes Arummanis (L. var. Arummanisa) freshness ", IOP Conference Series: Earth and Environmental Science, 2018

Publication

<1 %

14

Cheah, S.F.. "XAFS Spectroscopy Study of Cu(II) Sorption on Amorphous SiO₂ and γ -Al₂O₃: Effect of Substrate and Time on Sorption Complexes", Journal of Colloid And Interface Science, 19981201

Publication

<1 %

15

Taruna Shafa Arzam AR, Muliaty M Tahir, Hengki Wijaya. "The degreening of "Selayar" orange using ethephon: The color peel changes and ethephon residue", IOP Conference Series: Earth and Environmental Science, 2021

Publication

<1 %

16

epdf.pub
Internet Source

<1 %

17

kb.psu.ac.th
Internet Source

<1 %

18

www.intechopen.com
Internet Source

<1 %

19

Y.A. Purwanto, H. Okvitasari, S. Mardjan, U. Ahmad, Y. Makino, S. Oshita, S. Kuroki, Y. Kawagoe. "CHILLING INJURY IN GREEN MATURE 'GEDONG GINCU' MANGO FRUITS BASED ON THE CHANGES IN ION LEAKAGE", *Acta Horticulturae*, 2013

Publication

<1 %

Exclude quotes On

Exclude matches < 5 words

Exclude bibliography On

Extending of Mango (*Mangifera Indica* L.) Shelf Life with Combination of Zero Energy Cool Chamber (ZECC) Storage Technology, Washing and Packaging ¹⁾

Andi Dirpan*, Muhammad Tahir Sapsal, Mulyati M Tahir, Muspirah Djalal and Ashabul Firdaus

*dirpan@unhas.ac.id

Department of Agricultural Technology, Hasanuddin University Makassar 90245, Indonesia

1

2

ABSTRACT

3 Mangoes suffer up to a 20%-50% shrinkage, loss, and quality damage as a result of improper harvest
4 and post-harvest handling, as well as poor storage conditions. The presence of a post-harvest
5 technology system of Zero Energy Cool Chamber (ZECC) storage combined with pre-handling
6 treatment (washing and packaging) is one method of minimizing damage and extending the shelf life
7 of mangoes. The purpose of this study was to determine the mango golek's quality and shelf life by
8 using ZECC in combination with washing and packaging. This study used a completely randomized
9 design (CRD) with factorial patterns, specifically factor A (storage type) and factor B (packaging and
10 without packaging). The study's observation parameters were divided into two stages, with stage 1
11 consisting of physical parameters and stage 2 consisting of chemical, microbiological, and sensory
12 parameters. According to preliminary research, the best treatment is washing with 1% detergent + 0.5
13 percent Ca(OH)₂, which results in a smoother skin surface, less noticeable discoloration, and a cleaner
14 surface free of sap and dirt. Physical, chemical, microbiological, and sensory analysis of mango golek
15 (*Mangifera indica* L.) demonstrates that the ZECC storage technique can maintain fruit quality
16 optimally in combination with washing (chemical) and packaging treatment processes, and it can
17 effectively protect the mango golek's quality for up to 21 days.

18 **Keywords:** Mango, Quality, ZECC Storage

19

I. INTRODUCTION

1.1 Background

21 Indonesia possesses immense natural resource potential, particularly in horticultural crops like
22 mango. According to the Indonesian Central Statistics Agency, mango production reached 2,431,329
23 tons per year in 2014 and 2,178,833 tons per year in 2015, a decrease of 10.39 percent. Mango
24 productivity continues to be harmed by improper harvesting and post-harvest handling, which
25 degrades the quality of the mangoes. Additionally, storage conditions are insufficient during
26 agricultural product distribution and marketing, resulting in fruit depreciation. According to research
27 conducted in developing countries, improper harvesting and post-harvest handling can result in fruit
28 yield losses ranging from 20% to 50% (Dirpan et al. 2017)

29 Cold storage is one technique for postharvest handling. However, rural areas, which are
30 typically agricultural centers, have severe shortages of cold storage, such as refrigerators.
31 Additionally, the high operational costs associated with cold storage present a significant barrier to
32 farmers employing post-harvest handlers. Additionally, it produces freon, an environmentally
33 hazardous chemical (Dirpan et al. 2017). In light of the aforementioned issues, we require an energy-
34 free (zero energy) cold storage system that is also affordable (low cost) and environmentally friendly
35 (eco friendly), one of which is the Zero Energy Cool Chamber (ZECC) (Islam and Morimoto 2015).

36 The Zero Energy Cool Chamber (ZECC) is a cost-effective and environmentally friendly
37 method of storing fruits and vegetables following harvest. Due to the fact that ZECC does not require
38 electricity to operate, it is frequently referred to as an environmentally friendly fruit and vegetable
39 storage system (Dirpan 2019; Islam, Morimoto, and Hatou 2013) Additionally, this storage system is
40 cost effective due to the fact that it makes use of readily available materials such as bricks, sand,
41 plastic roofs, and water (Dirpan et al. 2017; Islam et al. 2013)

42 Recent years have seen an increase in research on fruit and vegetable storage methods utilizing
43 ZECC, as demonstrated by Kamilia et al. (2017) and Dirpan et al. (2018) studies examining the
44 quality of mangoes and tomatoes stored in ZECC (Ali 2017; Dirpan 2008). However, because fungi
45 grew around the mangoes in the aforementioned studies, ZECC was used in conjunction with pre-

46 handling treatments such as washing and packaging to minimize the possibility of mold and yeast
47 growth and to extend the shelf life of the golek mango. As a result, the purpose of this research were:
48 to determine the physical, chemical, microbiological, and sensory characteristics of mango golek
49 stored in a ZECC (Zero Energy Cool Chamber) in combination with washing and packaging
50 processes and to determine the shelf life of mangoes stored in a ZECC (Zero Energy Cool Chamber)
51 in combination with washing and packaging processes.

52 **II. Materials and Methods**

53 **II.1 Date and Location of Research**

54 This research was conducted from July to November 2019 at the Food Processing Laboratory
55 and the Chemical Laboratory of Food Quality Analysis and Supervision of the Food Science and
56 Technology Study Program, Department of Agricultural Technology, Faculty of Agriculture,
57 Hasanuddin University, as well as at the Research Activity Center (PKP) building and Lecturer
58 Housing Unhas Tamanlarea, Makassar.

59 **II.2 Instruments and materials**

60 The tools used in this research include a zero energy cool chamber (ZECC), polypropylene
61 plastic packaging, fruit racks, temperature and relative humidity sensors, hoses, scales, analytical
62 scales, and moisture, analyzer, colorimeter, penetrometer, digital hand refractometer, pH meter,
63 stirring rod, beaker, erlenmeyer flask, volumetric flask, dropper pipette, volume pipette, petri dish,
64 autoclave, bulb, micropipet, test tube, tube rack, laminar air flow (LAF), plates, spoons, knives, rags,
65 blenders.

66 Materials used in this study were 77 golek mango (main ingredient) with a maturity index of 2
67 (light green), aquadest, detergent, chlorine, calcium hydroxide ($\text{Ca}(\text{OH})_2$), sodium hydroxide
68 (NaOH), iodine, indicator phenolphthalein, alcohol, buffer pH 7, mineral water, starch indicator
69 (starch), potato dextrose agar (PDA) medium, inhibitor (chloramphenicol), cotton, and labels.

70 **II.3 Research procedure**

71 The research process is as follows:

72 **II.3.1 Preliminary research**

73 Mangoes are sorted, and then those that are not rotten or injured are selected for this research.
74 The mango is then graded according to its maturity level. Following that, the Zero Energy Cool
75 Chamber (ZECC) is chemically sterilized by spraying 0.5 percent chlorine + 70% alcohol. After that,
76 the mangoes are prepared and washed using water, detergent, and $\text{Ca}(\text{OH})_2$ in accordance with the
77 treatment method. After washing, Mangoes were air-dried and then stored in two different conditions:
78 ZECC and room temperature.

79 After that, the mango fruit was observed daily for changes until the eighth day of storage.

80 **II.3.2 Main research**

81 The following stage is mango that has received the best treatment during the washing process
82 (1 percent detergent + 0.5 percent $\text{Ca}(\text{OH})_2$), combined with post-harvest technology, specifically
83 packaging techniques utilizing Polypropylene (PP) plastic, and then returned to the sterilized ZECC.
84 Each day, the fruit is analyzed for damage, which is defined as shriveling, softening, dull skin color,
85 the appearance of black spots on the fruit's skin, and the presence of mold at the fruit's base.

86 **II.4 Research design**

87 The design of the research is divided into two stages. The first stage is to determine the optimal
88 treatment for washing mangoes using various washing ingredients, with the following treatments:

89 A_0 : Control (Without washing)

90 A_1 : Water-based cleaning

91 A_2 : 1% detergent + 0.25 % $\text{Ca}(\text{OH})_2$

92 A_3 : 1% detergent + 0.5% $\text{Ca}(\text{OH})_2$

93 Following with storage in ZECC and at room temperature, Physical parameters of the fruit skin
94 surface, color, sap, and impurities were observed visually.
95

96 The next step is, mango that received the best treatment during the washing process, combined
97 with packaging techniques utilizing Polypropylene (PP) plastic. It is then analyzed every three days
98 using a variety of observation parameters
99

100 **II.5 Data analysis**

101 The data obtained in the second phase of the study were compiled using a completely
102 randomized design (CRD) with a factorial pattern, namely factor A (type of storage) and factor B
103 (packaged and unpackaged). The research was carried out with three replications.

104 Data processing used quantitative descriptive method, all parameters were analyzed by analysis
105 of variance (ANOVA) with three replications. The differences for each treatment were further tested
106 using Duncan's test. The software used for data processing is Microsoft Excel 2016 and IBM SPSS
107 Statistics Version 23.

108 **II.6 Observation Parameter**

109 Observation parameters in stage 1 are physical parameters of fruit skin surface, color, sap and
110 dirt. Parameters observed in stage 2 include vitamin C, pH value, water content, total acid, total
111 dissolved solids, weight loss, skin color, hardness test, total microbe, and organoleptic test using 15
112 panelists.

114 **III. RESULT AND DISCUSSION**

116 **III.1 First Phase of Research**

117 The results of the storage of mangoes from the preliminary study showed that mangoes stored
118 at ZECC had better physical quality (visually) than mangoes stored at room temperature. Mangoes
119 stored in ZECC had smoother skin, less noticeable skin discoloration until the 8th day of storage,
120 fewer lenticel spots, and did not grow fungus on the skin surface. The fruit that was stored at room
121 temperature with a rougher skin surface (wrinkled), slightly noticeable skin discoloration, lenticel
122 spots began to appear on the 5th day of storage, as well as fungal growth in some mango samples.
123 These results indicate that storage using the ZECC method is good for extending the shelf life of
124 mangoes compared to storage at room temperature.

125 **III.1.1 Mango Skin Surface**

126 Visual observations of the mango skin's surface revealed that ZECC storage was better
127 compared to room temperature storage. Mango fruits stored in ZECC had smoother skin (not
128 wrinkled) than mango fruits stored at room temperature, which had wrinkled skin surface. The
129 absence of wrinkles in mangoes stored at ZECC is due to the relative humidity (RH) in a good storage
130 room, which is between 80% and 98.04 percent, as opposed to room temperature, which has a relative
131 humidity of 50% to 56.90 percent. This is consistent with Muchtadi (1992), who states that all
132 varieties of mango are susceptible to cold damage in the form of dark spots, uneven ripening, and
133 failure to produce adequate flavor and color, and that a relative humidity of 85-90 percent is required
134 to prevent wilting and softening of various fruits and vegetables (Muchtadi 1992).

135 The room temperature is higher than the temperature in the ZECC. ZECC has a temperature
136 range of 24-25°C, while the ambient temperature ranges from 26-31°C. Mango fruit stored at room
137 temperature transpired and respired at a faster rate than mango stored in ZECC, causing the mango
138 skin to wrinkle. Because respiration rate is related to the rate of quality deterioration, it can be used
139 to estimate the shelf life of fruit after harvest. As stated by Rizkia (2004) that the slower the rate of
140 respiration, the longer the fruit can be stored in its fresh state; conversely, the faster the rate of
141 respiration, the shorter the shelf life (Rizkia 2004).

142 **III.1.2 Skin color**

143 Mangoes are generally observed visually by observing how clearly the color change from green
144 to yellow appears on the mango skin. Mangoes stored at room temperature and in ZECC without
145 treatment/washing (control), as well as those washed with water and detergent + Ca(OH)₂ exhibited
146 no discernible color changes. On the sixth day of observation, the color changed to a slight yellow

147 hue. This color change occurs because mangoes, as climacteric fruits, accelerate the ripening process
 148 during storage. The maturation process that occurs concurrently with the breakdown of chlorophyll,
 149 resulting in the appearance of other color pigments such as yellow and red, causing the green color
 150 to degrade. This is in line with El-Zeftawi *et al.*, (1988), who stated that the level of chlorophyll
 151 content in green fruit decreases during the storage, other pigments begin to appear, turning the fruit
 152 yellow or orange (El-Zeftawi *et al.* 1988).

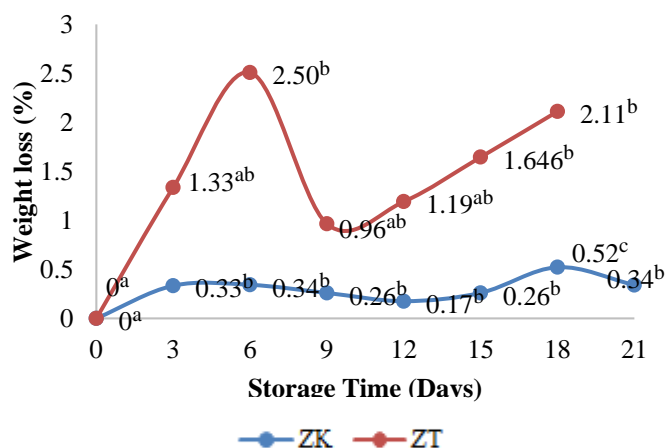
153 III.1.3 Sap and Dirt

154 For mango fruit washed with water, on day 6 DAW (day after washing), there were still
 155 remnants of sap attached to the surface of the mango fruit skin, although they were not particularly
 156 noticeable. However, there were a few lenticel spots and a change in color at the fruit's base on day 6
 157 DAW (day after washing) until the 8th day of DAW. While mangoes treated with 1% detergent +
 158 0.25 percent $\text{Ca}(\text{OH})_2$ can visually remove sap, the treatment was more effective at 1% + $\text{Ca}(\text{OH})_2$
 159 0.5 percent detergent immersion, which resulted in samples of mango fruit being more free of sap
 160 and dirt, resulting in a smoother surface with no noticeable changes up to 8 DAW. This is because
 161 1% detergent binds to oil and effectively removes or lifts dirt. Until the eighth day after DAW mango
 162 was treated with 1% detergent and 0.5 percent $\text{Ca}(\text{OH})_2$, no lenticel or fungal spots appeared at the
 163 base or on the surface of the fruit skin. The surface is smoother and burn-free because the detergent's
 164 surfactant active ingredients can remove the oil contained in the sap. Alkaline $\text{Ca}(\text{OH})_2$ solution can
 165 neutralize the acid in the sap attached to the golek mango cultivar's skin. This is consistent with
 166 Ahmad, S *et al* (2017)'s finding that the 1% + $\text{Ca}(\text{OH})_2$ 0.5 percent detergent treatment resulted in a
 167 lower mean score for reducing lenticel spots at 2 to 14 DAW when compared to the control (Ahmad
 168 *et al.* 2017). In accordance with Taqiyyah (2015), a combination of detergent and $\text{Ca}(\text{OH})_2$ is capable
 169 of removing sap and oil from the surface of the Gedong mango skin (Taqiyyah 2015).

170 III.2 Second Phase of Research

171 The second stage of this study involved determining the quality and shelf life of mangoes while
 172 they were stored. Mangoes that received the best washing treatment (1 percent detergent + 0.5 percent
 173 $\text{Ca}(\text{OH})_2$) were then given packaging treatment (using Polypropylene (PP) plastic and without
 174 packaging) and then analyzed for quality. Mangoes packaged with Polypropylene (PP) plastic can be
 175 stored in ZECC for 21 days, whereas mangoes packaged without Polypropylene plastic have a shelf
 176 life of only 18 days.

177 III.2.1 Weight Loss



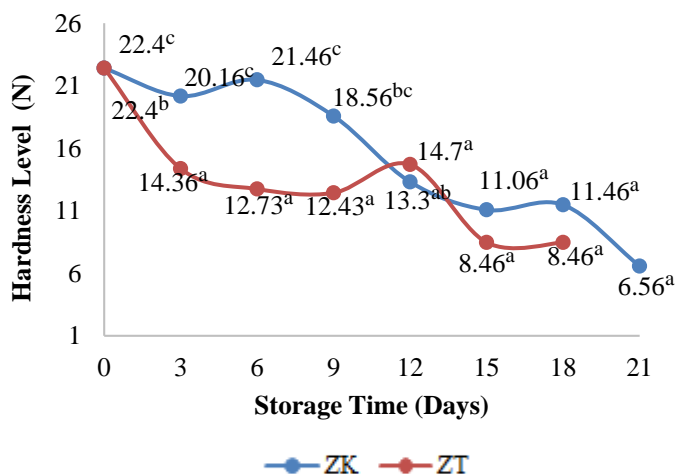
178 Figure 1. The weight loss of Mangoes During Storage. Values followed by different letters indicate treatment results that are
 179 significantly different ($p < 0.05$).
 180

181 During storage, the mango fruit's weight loss tends to increase. Unpackaged mangoes (ZT) lost
 182 approximately twice as much weight as packaged mangoes (ZK). This means that when packaging is
 183 used in combination with the ZECC storage technique, mangoes lose less weight. Unpackaged
 184 mangoes experienced a greater increase in weight loss due to a high evaporation rate (transpiration),
 185 whereas packaged mangoes experienced less water evaporation during storage. Water loss results in
 186 withering and shrinking. This is consistent with Winarno (2002), who states that the amount of water

187 in foods determines their freshness, appearance, and durability (Winarno 2002). If some of the water
 188 in the food evaporates, weight loss occurs, reducing the food's freshness, appearance, and durability.
 189 In addition to transpiration, weight loss is also influenced by the respiration process of mango
 190 fruit. Carbon loss can occur during the respiration process. Carbon compounds contained in the sugar
 191 in mangoes will bind and react with oxygen which will produce simple volatile compounds, namely
 192 water vapor and carbon dioxide so that the fruit will lose its weight. So in this case it is known that
 193 the respiration process can be suppressed by a combination of packaging and storage in ZECC. This
 194 is in accordance with the opinion of Syafutri et al., (2006), which states that the process of fruit
 195 respiration can be suppressed by combining packaging and storage at low temperatures (Syafutri,
 196 Pratama, and Saputra 2006).

197
 198
 199
 200

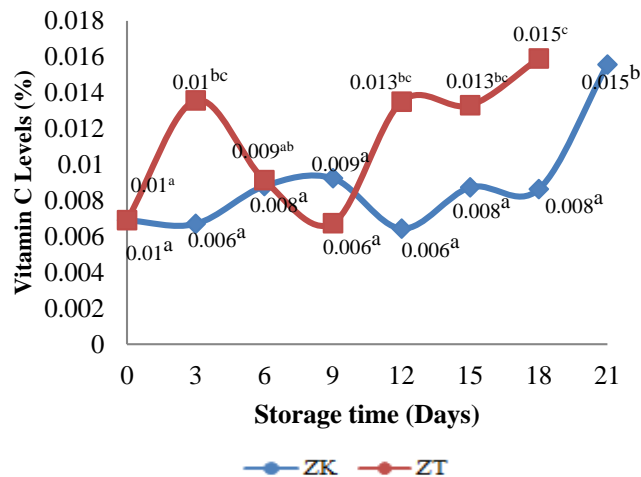
201 **III.2.2 Hardness Level**



202
 203 Figure 2. The Hardness Level of Mango Fruit During Storage. Values followed by different letters indicate treatment results that are
 204 significantly different ($p < 0.05$).

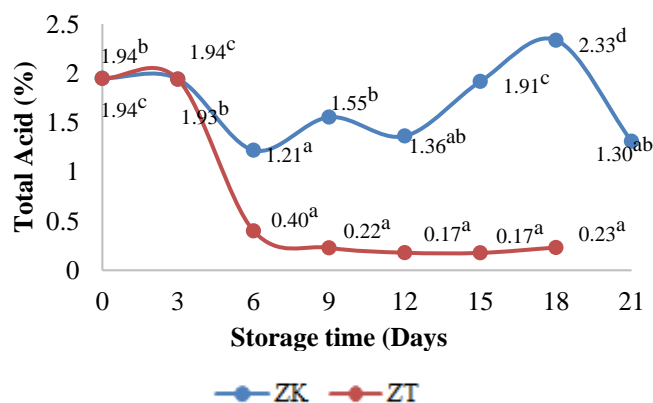
205 The ripening process of mangoes during storage results in changes in the level of mango fruit
 206 hardness. The ripening process in mangoes occurs concurrently with the conversion or degradation
 207 of protopectin to pectin, resulting in a decrease in cell wall rigidity. Mangoes without packaging
 208 treatment (ZT) had a greater loss of hardness than mangoes with packaged treatment (ZK). This is
 209 due to the fact that unpackaged mangoes have a higher respiration rate and a higher enzyme activity.
 210 The more actively these enzymes are, the softer the texture of the fruit. Meanwhile, the rapid rate of
 211 respiration causes the fruit tissue to rupture, resulting in the mango becoming soft. The mango with
 212 packaging treatment (ZK) can reduce the amount of oxygen received, thereby slowing the respiration
 213 process (maintained). This is consistent with Syafutri et al. (2006), who state that the decrease in
 214 hardness is also a result of the respiration and transpiration processes (Syafutri et al. 2006). The
 215 respiration process results in the breakdown of carbohydrates into simple compounds and tissue
 216 rupture, resulting in the mango becoming soft, whereas the transpiration process results in water
 217 evaporation, resulting in the mango becoming wilted.

218
 219
 220
 221
 222
 223
 224
 225

227 **III.2.3 Vitamin C levels**

228 Figure 3. Vitamin C Levels of Mangoes During Storage. Values followed by different letters indicate treatment results that are
 229 significantly different ($p < 0.05$).
 230

231 The levels of vitamin C (ascorbic acid) of mangoes during storage in ZECC tend to vary, both
 232 packaged in polypropylene plastic and mangoes without packaging. The significant increase in
 233 vitamin C levels of unpackaged mangoes until the end of storage was in line with the faster ripening
 234 process of mangoes compared to packaged mangoes. This is in accordance with Pantastico (1986),
 235 which states that ripe fruit will increase in acidity, and this increase occurs simultaneously with the
 236 climacteric pattern, while vitamin C levels will decrease when the maximum point of increase has
 237 been exceeded (withering stage) (Pantastico 1986). The ripening process of unpackaged mangoes is
 238 faster because the respiration process is greater than that of packaged mangoes. Mango packaging
 239 can regulate/minimize the respiration process of the fruit so that the freshness of the mango can be
 240 maintained. This is in accordance with Park et al., (2004), which states that Polypropylene (PP) plastic
 241 has high permeability properties which can regulate the rate of atmospheric absorption or respiration
 242 rate which can maintain fruit freshness longer (Park, Kim, and Yun 2004). The results of analysis of
 243 variance showed that mango without packaging treatment and mango with packaging treatment had
 244 a significant effect on vitamin C levels during storage. This is indicated by the value of vitamin C
 245 which was initially low and then increased until the end of storage. The increase or decrease in vitamin
 246 C is because the vitamin is unstable, easily oxidized when exposed to air (oxygen) and this process
 247 can be accelerated by storage temperature. This is in accordance with Tannenbaum (1976), stating
 248 that the reduction of O_2 will inhibit the degradation of ascorbate into dehydroascorbic acid and H_2O_2
 249 (Tannenbaum 1976). The resulting H_2O_2 will cause autoxidation so that it will increase the damage
 250 of vitamin C.

251 **III.2.4 Total Acid**

252 Figure 4. Total Acid Level of Mango Fruit During Storage. Values followed by different letters indicate treatment results that are
 253 significantly different ($p < 0.05$).
 254

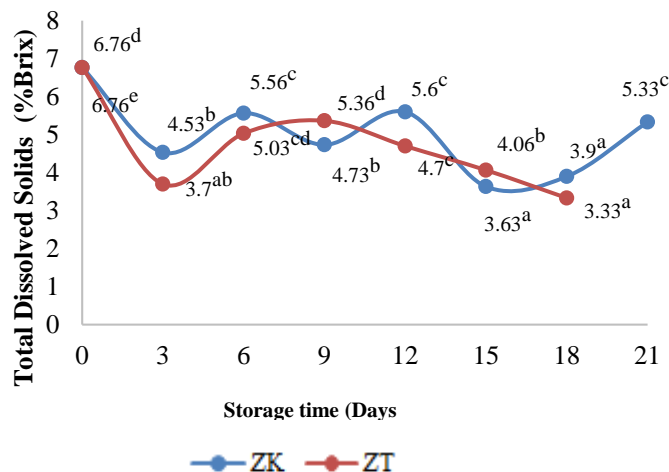
255 The total acid value of mango in ZECC storage, both packaged and unpackaged, tends to
 256 decrease, though the trend is variable. The percentage of total acid in the fruit decreases as the fruit

257 is stored. The decrease in the percentage of total acid is due to the respiration process's use of organic
 258 acids, as well as the use of organic acids by microbes in energy-consuming activities. This energy is
 259 obtained through the breakdown of the nutrients found in food. Organic acids are converted to sugars
 260 during the respiration process. Amalya et al. (2017) found in their research that the fruit's decreased
 261 organic acid value indicated that the fruit's ripening metabolism was functioning normally (Khairi,
 262 Falah, and Pamungkas 2017).

263 Total acid in mangoes that were not packaged (ZK) contained a greater proportion of total acid
 264 or degraded more rapidly than in packaged mangoes (ZK). This is due to the respiration process of
 265 unpackaged mangoes. Merynda et al. (2006) state that when mangoes are not packaged, the
 266 respiration process cannot be minimized due to the abundant O₂ in the environment (Syafutri et al.
 267 2006).

268 III.2.5 Total Dissolved Solids (TDS)

269 Mangoes' total dissolved solids (packaged and unpackaged) exhibit a fluctuating graph.
 270 Unpackaged mangoes (ZT) underwent a maximum ripening process, as indicated by the percentage
 271 of TDS value increasing significantly at first and then gradually decreasing until the end of storage.
 272 The increase in TDS is a result of starch hydrolysis during ripening process. While the decrease in
 273 TDS occurs as a result of the abundant O₂ available in the environment, which prevents the respiration
 274 process from being suppressed. Thus, glucose as the result of starch hydrolysis then was consumed
 275 during the respiration process, resulting in a rapid decrease in the sugar content of the fruit. Pantastico
 276 (1993) confirms this by stating that during ripening, starch is hydrolyzed into simple compounds that
 277 serve as a source of energy during the respiration process (Pantastico 1986). At this point, the sucrose
 278 has been converted back to glucose and fructose. The decrease in total sugar content of unpackaged
 279 mangoes occurred as the mango fruit began to ripen, at which point the starch content began to
 280 decrease and the activity of the invertase enzyme decreased, resulting in a decrease in sugar content.
 281 The mango with packaging (ZK) has the ability to maintain the fruit's ripening process, as indicated
 282 by the predominant fluctuating TDS value. This demonstrates that by combining packaging and
 283 storage in ZECC, the rate of decrease in the percentage of TPT in mangoes can be slowed.



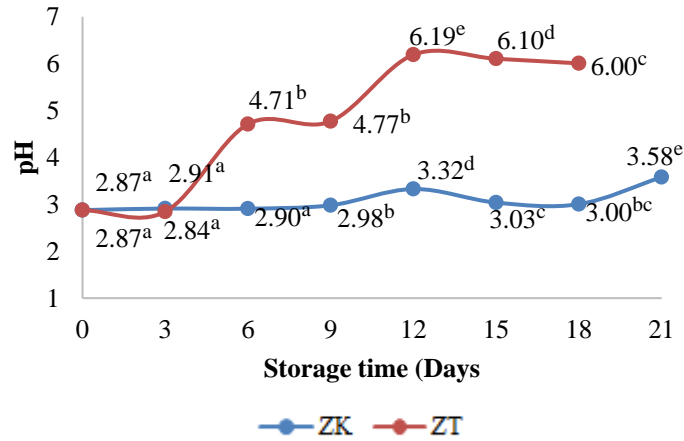
284 Figure 5. Total Dissolved Solids of Mango Fruit During Storage. Values followed by different letters indicate treatment results that are
 285 significantly different (p<0.05).
 286

287 This variable total dissolved solids value is also a result of the fruit's non-uniform maturity
 288 level. Non-uniform fruit ripeness causes abnormal respiratory activity so that the breakdown process
 289 of simple sugars varies. In general, changes in total dissolved solids content increased at the maximum
 290 point of storage and then decreased until the fruit began to rot on the final day of storage. This is
 291 consistent with Biale and Young's (1971) observation that the general trend is for a rapid increase in
 292 sugar content followed by a decline; in climacteric fruit, this condition becomes a marker (Biale and
 293 Young 1971).

294 III.2.6 Degree of Acidity (pH)

295 According to the graph, mango fruit are acidic, with a pH value ranging between 2 and 6 during
 296 storage. The ripening of mangoes alters the pH value of the fruit. Without packaging treatment (ZT),
 297 mango matured rapidly (maximum), increasing the pH value. It is not the case with packaged

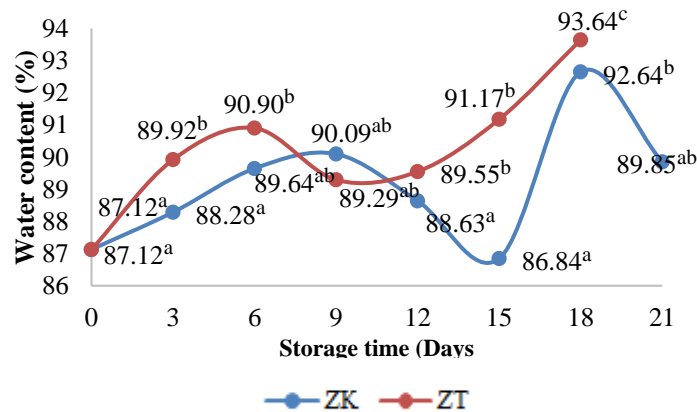
298 mangoes (ZK), as their ripening process is slowed, resulting in a stable pH value throughout storage.
 299 As the mango ripens, the acid content decreases while the simple sugars increase, as indicated by the
 300 decrease in total acid content. The pH value is directly proportional to vitamin C levels and inversely
 301 proportional to total acidity, as shown in the graph. This is consistent with Amalya et al., (2017), who
 302 state that changes in pH indicate changes in the composition of the fruit's cell fluid as it matures; the
 303 pH value that tends to be high is related to relatively high ascorbic acid (vitamin C) levels during
 304 storage; this change indicates that the fruit's metabolism affects the pH value (Khairi et al. 2017).



305 Figure 6. pH Value (Degree of Acidity) Mango Fruit During Storage. Values followed by different letters indicate treatment results
 306 that are significantly different ($p < 0.05$).
 307

308 III.2.7 Water content

309 The water content of mangoes stored in the ZECC method varied slightly during storage. When
 310 compared to unpackaged mangoes, packaged mangoes (ZK) are able to maintain changes in water
 311 content during storage. This is because PP packaged mangoes have a high permeability, which
 312 minimizes changes in water content during storage. This is consistent with Schwartz (2009), who
 313 states that because of the packaging, ambient air cannot easily enter the material, thereby inhibiting
 314 the process of water exchange during storage (Schwartz 2009).



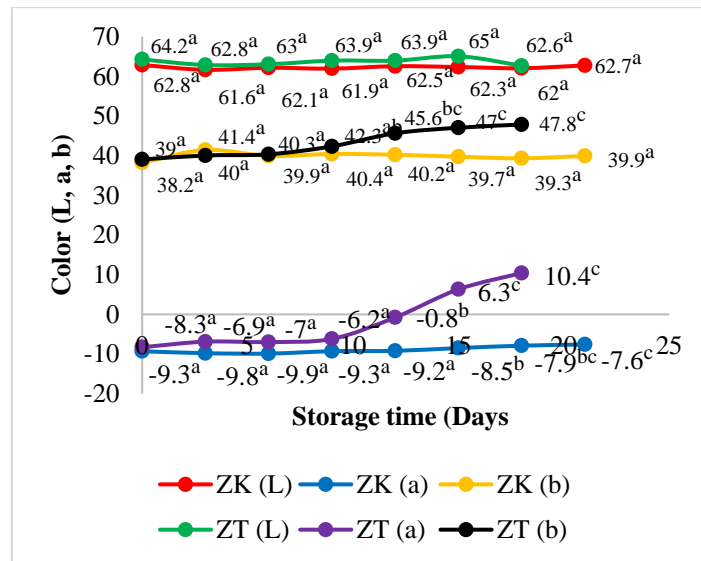
315 Figure 7. Water Content of Mangoes During Storage. Values followed by different letters indicate treatment results that are significantly
 316 different ($p < 0.05$).
 317

318 Due to the high humidity in ZECC storage, which reached 80-90 percent, mango fruit
 319 experienced an increase and decrease in water content during storage. Due to the high humidity level
 320 in the ZECC room, moisture absorption from the environment into the stored mango is possible. The
 321 longer the storage time, the higher the water content will remain. According to Herawati (2008), a
 322 significant factor influencing the decline in the quality of food products is changes in the product's
 323 water content, which can be influenced by the room's temperature and humidity during storage
 324 (Herawati 2008). This opinion is backed up by Retnani et al., (2009), who state that the high humidity
 325 of the storage room can result in the absorption of water vapor from the air into the foodstuffs,
 326 resulting in an increase in water content (Retnani et al. 2009).

327 Additionally, the increase in water content during storage is a result of the mangoes' respiration
 328 process. During storage, the fruit undergoes a ripening process that includes the conversion of starch
 329 to simple sugars ($C_6H_{12}O_6$). These simple sugars then interact with the oxygen (O_2) in the chamber,

330 increasing the rate of water (H₂O) formation in the fruit. This is consistent with Nurhayati S (2004),
 331 who states that one of the causes of changes in the water content of fruit is the respiration process,
 332 during which water is formed as a result of sugar reorganization into simpler compounds.

333 **III.2.8 Color**



334 Figure 8. Analysis of Mango Skin Color During Storage. Values followed by different letters indicate treatment results that are
 335 significantly different (p<0.05).
 336

337 The L* value indicates the brightness level of the mango fruit, which indicates the reflected
 338 light that produces achromatic colors of white, gray and black, ie from a value of 0 (black) – 100
 339 (white). The L* value of unpackaged and packaged mangoes had a very small decrease in lightness
 340 value during storage. The range of changes in the L* value from 65-62 indicates a slight decrease in
 341 brightness level during storage. The longer the fruit is stored, the lower the brightness level of the
 342 mango. According to Ahmad et al., (2014), that the brightness level of the color will decrease which
 343 will be directly proportional to the longer the shelf life, the fruit will lead to spoilage in the end
 344 (Ahmad, Darmawati, and Refilia 2014). The decreasing brightness level of the mango skin color is
 345 caused by changes in the chlorophyll content of the fruit. This is in accordance with the statement of
 346 Syafutri et al., (2006), which states that the reduced level of color brightness in fruit during storage
 347 is caused by reduced chlorophyll content in fruit skins and the appearance of carotenoids (Syafutri et
 348 al. 2006).

349 The a* value is a value that shows the gradation of green to red. A mixed red-green chromatic
 350 color with a value of +a* (positive) from 0 to +80 for red and a value of -a* (negative) from 0 to -80
 351 for green. The a* value of mango tends to increase during the storage process. Mangoes tend to be
 352 green, indicated by an a* value below 0, but the longer the storage time, the color of the fruit moves
 353 to red. The significant increase in a* value was caused by the high respiration rate of unpackaged
 354 mangoes so that the degradation of chlorophyll was also rapid which had the effect of accelerating
 355 the synthesis of pigment (color change) of the fruit. This is in accordance with the opinion of
 356 Masfufatun et al. (2015), which states that a high respiration rate will also cause chlorophyll
 357 degradation and pigment synthesis to be fast, consequently accelerating color changes (Masfufatun,
 358 Kumala, and Rahayuningsih 2009).

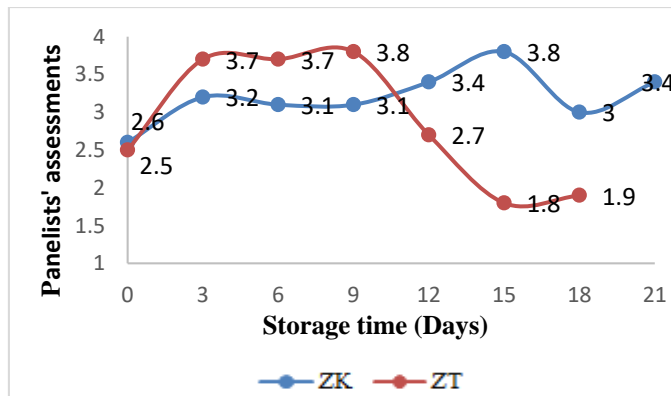
359 The b* value indicates the color gradation to yellow. A mixed blue-yellow chromatic color
 360 with a +b* (positive) value from 0 to +70 for yellow and a -b* (negative) value from 0 to -70 for
 361 blue. Based on the graph above, it shows that unpackaged mangoes have a slowly increasing b* value
 362 during storage compared to packaged mangoes whose b*_ values tend to be stable until the end of
 363 storage. The results of the measurement of the b* value show that the longer the storage, the yellow
 364 color of the mango will be clearer. The increasing b* value in unpackaged mangoes indicates that the
 365 fruit is getting more mature than the packaged mangoes during storage. This is in accordance with
 366 the statement of Kusumiyati et al., (2018), which states that the longer the storage, the yellow color
 367 of the mango is more clearly marked by the higher the mean b* value. The higher the b* value in the
 368 mango can be indicated the higher the ripeness level of the fruit (Kusumiyati et al. 2018).

369

370

371 III.2.9 Organoleptic test

372 III.2.9.1 Color

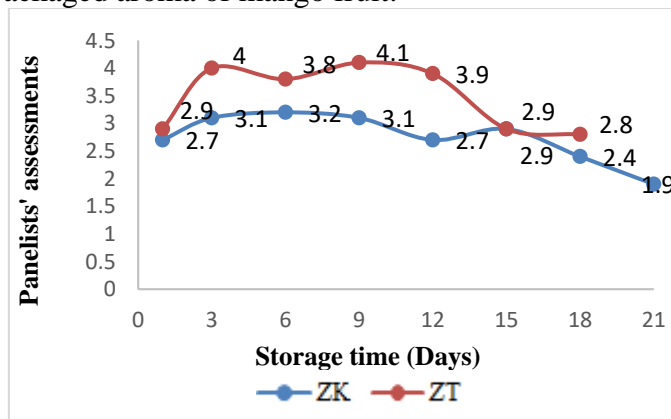


373 Figure 9. Results of Organoleptic Testing on Mango Color in ZECC Storage

375 The changes in panelists' assessments of organoleptic color parameters in mangoes were due to
 376 the nature of mangoes undergoing post-harvest ripening (after harvesting), specifically that the color
 377 will change during the storage process due to chlorophyll degradation into other pigments. The
 378 panelists' assessment of mangoes with packaging treatment (ZK) tended to remain stable until the end
 379 of storage, with an average value of 3 (slightly similar), whereas mangoes without packaging (ZT)
 380 maintained an average value of 4 (similar) until the ninth day of storage, when it decreased until the
 381 end of storage. This demonstrates that mangoes treated with packaging can help preserve or delay the
 382 color change of mangoes stored in ZECC. Packaging treatment on mangoes can slow the respiration
 383 process, resulting in a slower color change and maturation and aging process. This is consistent with
 384 Kamilia (2017), who states that a faster respiration rate can accelerate the senescence process, which
 385 results in a more rapid color change.

386 III.2.9.2 Aroma

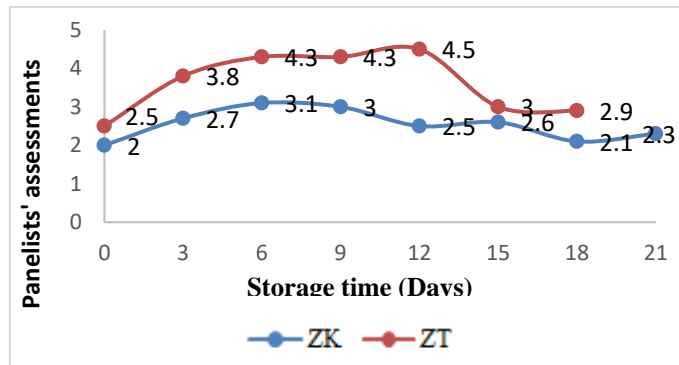
387 The panelists' evaluations of the mango aroma parameters revealed a range of results but a
 388 consistent pattern of increasing and then decreasing until the end of storage. In terms of fruit aroma,
 389 panelists prefer the unpackaged aroma of mango fruit.



390 Figure 10. Results of Organoleptic Testing on Mango Aroma in ZECC Storage

392 The high acceptance of unpackaged mango aroma (ZT) is a result of the increasing ripening
 393 process (perfect ripening), which results in an increase in the production of volatile components.
 394 While the packaged mango (ZK) took longer to decompose, the panelists generally disliked it due to
 395 the incomplete ripening process, which resulted in a low flavor. This is consistent with Muchtadi
 396 (1992), who stated that ripening typically results in an increase in the content of simple sugars, which
 397 imparts a sweet flavor, as well as an increase in the production of volatile substances, which imparts
 398 a distinctive fruit flavor.

399 III.2.9.3 Taste



Gambar 11. Results of Organoleptic Testing on Mango Taste in ZECC Storage

400
401

402 The results of organoleptic tests on mangoes stored at ZECC showed that the panelists'
 403 assessment of fruit taste increased and then decreased until the end of storage. The range of values
 404 between 3-5 (based on the graph) shows that the panelists' assessment of unpackaged mangoes (ZT)
 405 is dominantly preferable to mangoes with packaged treatment (ZK) with a value of 2-3. The high
 406 rating for unpackaged mangoes is because the mangoes undergo an even ripening process during
 407 storage, resulting in a distinctive taste and good color which are preferred by panelists (Ali 2017).
 408 The sweet taste is due to the change in the starch content of the fruit to sugar during storage. This is
 409 in accordance with the statement of Mulyati (2012), that changes during the ripening process are
 410 changes in starch and fat reserve materials into various sugars (Mulyati 2012). The mango with
 411 packaging (ZK) undergoes a slow ripening process due to its low respiration rate in the presence of
 412 packaging, but it takes longer to decay or damage in ZECC storage.

413

414 **IV.2.9.4 Texture**

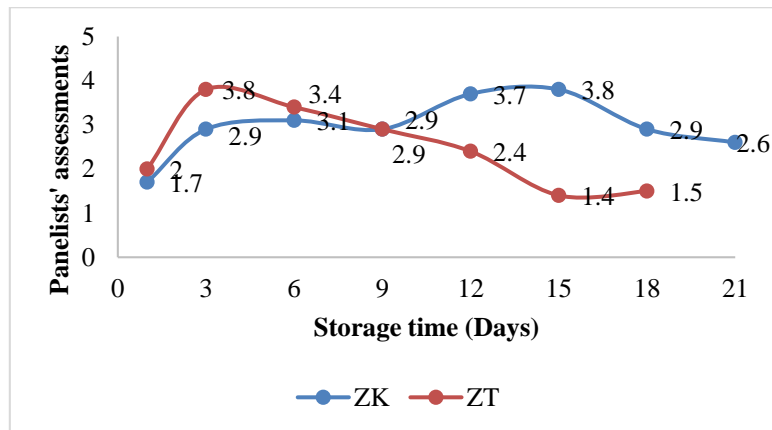


Figure 12. Results of Organoleptic Testing on Mango Texture in ZECC Storage

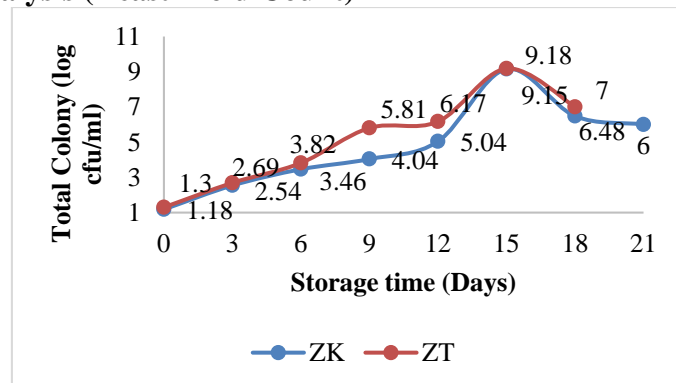
415
416

417 Panelists determined that mango with packaged treatment (ZK) (mean value 3-4) was preferable
 418 in terms of texture because the level of hardness did not decrease significantly (soft), as opposed to
 419 mango without packaged treatment (ZT) (mean value 2-3). The texture began as hard, which the
 420 panelists disliked, then softened slightly, which the panelists liked, and finally became extremely soft
 421 due to damage/rotting, which the panelists disliked. When the qualitative (organoleptic test of texture
 422 parameters) analysis of mango fruit is combined with quantitative analysis (with a penetrometer), it
 423 is discovered that the level of hardness (the process of hardness decreasing) is directly proportional
 424 during storage.

425 Mangoes' softening texture is caused by the ripening process that occurs during storage.
 426 Maturation occurs concurrently with the conversion or degradation of insoluble protopectin to soluble
 427 pectin. The reshuffle occurs as a result of the action of enzymes such as pectin methyl esterase, which
 428 softens the fruit. Proteopectin levels in the fruit decrease as the fruit ripens, while pectin levels
 429 increase. This is in accordance with Afrazak et al., (2014), that as fruit ripens and stores, some of the
 430 water-insoluble protopectin converts to water-soluble pectin, reducing the cohesion of the cell walls
 431 that connect cells, resulting in a decrease in texture or fruit hardness and the fruit becoming soft
 432 (Johansyah and Kusdiantini 2014). Additionally, the rate of respiration has an effect on the degree of
 433 hardness or texture. Unpackaged mangoes with a high respiration rate cause the fruit's tissue to

434 rupture and enzyme activity to accelerate, resulting in a softer fruit texture. The mango with
435 packaging treatment (ZK) can reduce the amount of oxygen received, thereby slowing the respiration
436 process (maintained).

437 III.2.10 Microbial Analysis (Yeast Mold Count)



438
439 Figure 13. Mold and Yeast cell count on Mangoes During Storage in ZECC

440 According to the graph, the results of microbial analysis (mold and yeast counts) on mango
441 fruit storage in ZECC indicated that yeast mold growth continued to increase and then decreased
442 gradually until the end of storage. Microbial growth (mold and yeast) that began low/small and then
443 increased to a maximum growth peak on the 15th day generally indicated that the mangoes' quality
444 deteriorated during storage and gradually entered the senescence phase. This also demonstrates that
445 mangoes with a relatively high sugar content and a low pH provide an ideal environment for molds
446 and yeasts to grow to their maximum growth capacity during storage. This is consistent with Seema
447 R (2015) statement that fruit with a high sugar content and a low/acidic pH (pH range between 3-8)
448 promotes the growth of fungi (mold/yeast) after the fruit is harvested (Rawat 2015).

449 Mango without packaging (ZT) exhibited a greater increase in the growth of the dominant
450 mold/yeast than mango with packaging (ZK). This demonstrates that by combining calcium
451 hydroxide washing with packaging on mangoes stored in ZECC, the rate of microbial growth can be
452 slowed or suppressed, thereby extending the fruit's life phase. Certain microbes require oxygen to
453 grow, which can be suppressed through packaging. This is consistent with the opinion of Ira M et al.
454 (2017), who state that treating fruit with packaging technology can suppress the air activity required
455 by microbes, thereby slowing the growth rate of pathogenic microbes (Mulyawanti, Syaefullah, and
456 Amiarsi 2018)

457 458 459 IV. Conclusions

460
461 It can be concluded that analysis of the quality of golek mango (*Mangifera indica* L.)
462 physically, chemically, microbiologically, and sensory in the Zero Energy Cool Chamber (ZECC)
463 storage technique shows that ZECC can maintain optimal fruit quality through a washing treatment
464 process (chemically) in combination with packaging. In addition, the Zero Energy Cool Chamber
465 (ZECC) storage method with a combination of washing and packaging treatments is effective in
466 maintaining the quality of mangoes up to 21 days of storage.

467 468 V. Acknowledgment

469 This research was funded by the Directorate General of Research and Development,
470 Ministry of Research, Technology and Higher Education, Republic of Indonesia, through
471 LPPM Unhas : Penelitian Terapan 2020.

472 473 References

- 475 Ahmad, Sutopo, Roedhy Poerwanto, and Suryo Wiyono. 2017. "Keefektifan Bahan Pencuci Dan
476 Pencegah Penyakit Terhadap Kualitas Buah Mangga CV. Gedong Gincu Dan Arumanis (The
477 Effectiveness of Washing Materials and Disease Protecting Agent on the Quality of Mango
478 Fruit Cv. Gedong Gincu and Arumanis)." *Jurnal Hortikultura* 27(2):253–60.
- 479 Ahmad, Usman, Emmy Darmawati, and Nur Rahma Refilia. 2014. "Kajian Metode Pelilinan
480 Terhadap Umur Simpan Buah Manggis (*Garcinia Mangostana*) Semi-Cutting Dalam
481 Penyimpanan Dingin." *Jurnal Ilmu Pertanian Indonesia* 19(2):104–10.
- 482 Ali, Kamilia Nur Yaumil. 2017. "Mutu Buah Mangga (*Mangifera Indica* L.) Dan Tomat
483 (*Lycopersicum Esculentum* Mill.) Yang Disimpan Pada ZECC (Zero Energy Cool Chamber)."
484 Universitas Hasanuddin.
- 485 Biale, J. B. and R. Young. 1971. *The Avocado Pear. Dalam Hulme, A.C. The Biochemistry of*
486 *Fruitand Their Produce*. london: Academic Press.
- 487 Dirpan, A. 2019. "The Quality of Tomato (*Lycopersicum Esculentum* Mill.) Stored on ZECC (Zero
488 Energy Cool Chamber)." P. 12012 in *IOP Conference Series: Earth and Environmental*
489 *Science*. Vol. 270. IOP Publishing.
- 490 Dirpan, Andi. 2008. *ZECC (Zero Energy Cool Chamber) Penyimpanan Dingin Yang Murah Dan*
491 *Ramah Lingkungan Untuk Memperpanjang Masa Simpan Buah Dan Sayur Setelah Panen*.
492 Makassar: Universitas Hasanuddin.
- 493 Dirpan, Andi, Muhammad Tahir Sapsal, Abdul Kadir Muhammad, Mulyati M. Tahir, and
494 Rahimuddin. 2017. "Evaluation of Temperature and Relative Humidity on Two Types of Zero
495 Energy Cool Chamber (ZECC) in South Sulawesi, Indonesia." *IOP Conference Series: Earth*
496 *and Environmental Science* 101:012028.
- 497 El-Zeftawi, B. M., L. Brohier, L. Dooley, F. H. Goubran, R. Holmes, and B. Scott. 1988. "Some
498 Maturity Indices for Tamarillo and Pepino Fruits." *Journal of Horticultural Science*
499 63(1):163–69.
- 500 Herawati, Heny. 2008. "Penentuan Umur Simpan Pada Produk Pangan." *Jurnal Litbang Pertanian*
501 27(4):124–30.
- 502 Islam, M. P. and T. Morimoto. 2015. "ScienceDirect Evaluation of a New Heat Transfer and
503 Evaporative Design for a Zero Energy Storage Structure." *Solar Energy* 118:469–84.
- 504 Islam, M. P., T. Morimoto, and K. Hatou. 2013. "Dynamic Optimization of inside Temperature of
505 Zero Energy Cool Chamber for Storing Fruits and Vegetables Using Neural Networks and
506 Genetic Algorithms." *Computers and Electronics in Agriculture* 95:98–107.
- 507 Johansyah, Afrazak and Endang Kusdiantini. 2014. "Pengaruh Plastik Pengemas Low Density
508 Polyethylene (LDPE), High Density Polyethylene (HDPE) Dan Polipropilen (PP) Terhadap
509 Penundaan Kematangan Buah Tomat (*Lycopersicon Esculentum*. Mill)." *Anatomi Fisiologi*
510 22(1):46–57.
- 511 Khairi, Amalya Nurul, Affan Fajar Falah, and Agung Putra Pamungkas. 2017. "Analisis Mutu
512 Pascapanen Melon (*Cucumis Melo* L.) Kultivar Glamour Sakata Selama Penyimpanan."
513 *CHEMICA: Jurnal Teknik Kimia* 4(2):47–52.
- 514 Kusumiyati, Kusumiyati, Farida Farida, Wawan Sutari, and Syariful Mubarak. 2018. "Kualitas
515 Buah Mangga Selama Penyimpanan Pada Keranjang Anyaman Bambu Dengan Identifikasi
516 Ruang Warna L*, A* Dan B." *Kultivasi* 17(2):628–32.
- 517 Masfufatun, Widaningsih, N. Kumala, and T. Rahayuningsih. 2009. "Pengaruh Suhu Dan Waktu
518 Penyimpanan Terhadap Vitamin c Dalam Jambu Biji (*Psidium Guajava*)." *Universitas Wijaya*
519 *Kusuma, Surabaya*.
- 520 Muchtadi, Deddy. 1992. *Fisiologi Pasca Panen Sayuran Dan Buah-Buahan: Petunjuk*
521 *Laboratorium*. Institut Pertanian Bogor.

- 522 Mulyati. 2012. *Sayur-Sayuran, Buah-Buahan Penanganan Dan Pengolahannya*. Makassar: CV.
523 Indo media.
- 524 Mulyawanti, Ira, Enrico Syaefullah, and Dwi Amiarsi. 2018. “Teknologi Pengemasan Atmosfir
525 Termodifikasi (Modified Atmosphere Packaging/Map) Dan Vakum Pada Buah Durian.”
- 526 Pantastico, E. B. 1986. *Fisiologi Pascapanen, Penanganan Dan Pemanfaatan Buah-Buahan Dan*
527 *Sayur-Sayuran Tropika Dan Subtropika (Terjemahan Kamariyani 1997)*. Yogyakarta: Gajah
528 Mada University Press.
- 529 Park, T., Y. A. Kim, and J. Yun. 2004. “The Need for Collaboration in the Supply Chain For
530 Successful Direct Shipments.” in *Proceedings of the Thirty-Third Annual Meeting of the*
531 *Western Decision Sciences Institute*.
- 532 Rawat, Seema. 2015. “Food Spoilage: Microorganisms and Their Prevention.” *Asian Journal of*
533 *Plant Science and Research* 5(4):47–56.
- 534 Retnani, Y., W. Widiarti, I. Amiroh, L. Herawati, and K. B. Satoto. 2009. “Daya Simpan Dan
535 Palatabilitas Wafer Ransum Komplit Pucuk Dan Ampas Tebu Untuk Sapi Pedet.” *Media*
536 *Peternakan* 32(2):130–36.
- 537 Rizkia. 2004. “Kajian Laju Respirasi Dan Perubahan Mutu Buah Mangga Gedong Gincu Selama
538 Penyimpanan Dan Pematangan Buatan.” Institut Pertanian Bogor.
- 539 Schwartz, Naomi. 2009. “Pengaruh Jenis Bahan Pengemas Terhadap Kualitas Cabe Merah Segar
540 Selama Penyimpanan Dingin.” Universitas Sumatra Utara.
- 541 Syafutri, Merynda I., F. Pratama, and D. Saputra. 2006. “Sifat Fisik Dan Kimia Buah Mangga
542 (Mangifera Indica L.) Selama Penyimpanan Dengan Berbagai Metode Pengemasan.” *Jurnal*
543 *Teknologi Dan Industri Pangan* 17(1):1–11.
- 544 Tannenbaum. 1976. *Vitamins and Mineral*. New York (US: MerceL Dekker.
- 545 Taqqiyah, Affifah. 2015. “Pengaruh Penambahan Fungisida Pada Bahan Pencuci Serta Suhu
546 Penyimpanan Terhadap Peningkatan Kualitas Mangga. (Mangifera Indica L.)”
- 547 Winarno. 2002. *Fisiologi Lepas Panen Produk Hortikultura*. Bogor: M-Brio Press.
- 548

Acknowledgement

External

Inbox

r

ram kishan <rkishan05@rediffmail.com> Fri, Sep 17, 2021, 8:39 PM

to me

Dear Author,

I am pleased to acknowledge your paper for possible publication in IJASS and is assigned number MS#8072 for future correspondence. Kindly suggest reviewers.

Thanks

Dr.Ram Kishan

Chief-Editor,IJASS

A

Revision: revision

Reviewed 8072

External

Inbox



ram kishan <rkishan05@rediffmail.com> Wed, Sep 29, 2021, 7:27 AM

to me

Please find attached herewith your paper reviewed by referee. Kindly resubmit it for final decision after incorporating all the suggestions.

Thanks

Dr.Ram Kishan
Chief-Editor,IJASS

Extending of Mango (*Mangifera Indica L.*) Shelf Life with Combination of Zero Energy Cool Chamber (ZECC) Storage Technology, Washing and Packaging¹⁾

ABSTRACT

Mangoes suffer up to a 20%-50% shrinkage, loss, and quality damage as a result of improper harvest and post-harvest handling, as well as poor storage conditions. The presence of a post-harvest technology system of Zero Energy Cool Chamber (ZECC) storage combined with pre-handling treatment (washing and packaging) is one method of minimizing damage and extending the shelf life of mangoes. The purpose of this study was to determine the mango golek's quality and shelf life by using ZECC in combination with washing and packaging. This study used a completely randomized design (CRD) with factorial patterns, specifically factor A (storage type) and factor B (packaging and without packaging). The study's observation parameters were divided into two stages, with stage 1 consisting of physical parameters and stage 2 consisting of chemical, microbiological, and sensory parameters. According to preliminary research, the best treatment is washing with 1% detergent + 0.5 percent Ca(OH)₂, which results in a smoother skin surface, less noticeable discoloration, and a cleaner surface free of sap and dirt. Physical, chemical, microbiological, and sensory analysis of mango golek (*Mangifera indica L.*) demonstrates that the ZECC storage technique can maintain fruit quality optimally in combination with washing (chemical) and packaging treatment processes, and it can effectively protect the mango golek's quality for up to 21 days.

Commented [U1]: Change with : This study aimed

Keywords: Mango, Quality, ZECC Storage

Commented [U2]: I recommend modifying the keywords, eliminate those that are in the title, and replace them by others to promote and give more information about your work

I. INTRODUCTION

Commented [U3]: No need to put this

1.1 Background

Indonesia possesses immense natural resource potential, particularly in horticultural crops like mango. According to the Indonesian Central Statistics Agency, mango production reached 2,431,329 tons per year in 2014 and 2,178,833 tons per year in 2015, a decrease of 10.39 percent. Mango productivity continues to be harmed by improper harvesting and post-harvest handling, which degrades the quality of the mangoes. Additionally, storage conditions are insufficient during agricultural product distribution and marketing, resulting in fruit depreciation. According to research conducted in developing countries, improper harvesting and post-harvest handling can result in fruit yield losses ranging from 20% to 50% (Dirpan et al. 2017)

Commented [U4]: Add space

Commented [U5]: Be consistent post-harvest or postharvest ??

Cold storage is one technique for postharvest handling. However, rural areas, which are typically agricultural centers, have severe shortages of cold storage, such as refrigerators. Additionally, the high operational costs associated with cold storage present a significant barrier to farmers employing post-harvest handlers. Additionally, it produces freon, an environmentally hazardous chemical (Dirpan et al. 2017). In light of the aforementioned issues, we require an energy-free (zero energy) cold storage system that is also affordable (low cost) and environmentally friendly (eco friendly), one of which is the Zero Energy Cool Chamber (ZECC) (Islam and Morimoto 2015).

Commented [U6]: Be consistent post-harvest or postharvest ??

The Zero Energy Cool Chamber (ZECC) is a cost-effective and environmentally friendly method of storing fruits and vegetables following harvest. Due to the fact that ZECC does not require electricity to operate, it is frequently referred to as an environmentally friendly fruit and vegetable storage system (Dirpan 2019; Islam, Morimoto, and Hatou 2013). Additionally, this storage system is cost effective due to the fact that it makes use of readily available materials such as bricks, sand, plastic roofs, and water (Dirpan et al. 2017; Islam et al. 2013)

Recent years have seen an increase in research on fruit and vegetable storage methods utilizing ZECC, as demonstrated by Kamilia et al. (2017) and Dirpan et al. (2018) studies examining the quality of mangoes and tomatoes stored in ZECC (Ali 2017; Dirpan 2008). However, because fungi grew around the mangoes in the aforementioned studies, ZECC was used in conjunction with pre-handling treatments such as washing and packaging to minimize the possibility of mold and yeast growth and to extend the shelf life of the golek mango. As a result, the

Commented [U7]: Put space

purpose of this research were: to determine the physical, chemical, microbiological, and sensory characteristics of mango golek stored in a ZECC (Zero Energy Cool Chamber) in combination with washing and packaging processes and to determine the shelf life of mangoes stored in a ZECC (Zero Energy Cool Chamber) in combination with washing and packaging processes.

II. Materials and Methods

II.1 Date and Location of Research

This research was conducted from July to November 2019 at the Food Processing Laboratory and the Chemical Laboratory of Food Quality Analysis and Supervision of the Food Science and Technology Study Program, Department of Agricultural Technology, Faculty of Agriculture, Hasanuddin University, as well as at the Research Activity Center (PKP) building and Lecturer Housing Unhas Tamanlarea, Makassar.

II.2 Instruments and materials

The tools used in this research include a zero energy cool chamber (ZECC), polypropylene plastic packaging, fruit racks, temperature and relative humidity sensors, hoses, scales, analytical scales, and moisture, analyzer, colorimeter, penetrometer, digital hand refractometer, pH meter, stirring rod, beaker, erlenmeyer flask, volumetric flask, dropper pipette, volume pipette, petri dish, autoclave, bulb, micropipet, test tube, tube rack, laminar air flow (LAF), plates, spoons, knives, rags, blenders.

Materials used in this study were 77 golek mango (main ingredient) with a maturity index of 2 (light green), aquadest, detergent, chlorine, calcium hydroxide ($\text{Ca}(\text{OH})_2$), sodium hydroxide (NaOH), iodine, indicator phenolphthalein, alcohol, buffer pH 7, mineral water, starch indicator (starch), potato dextrose agar (PDA) medium, inhibitor (chloramphenicol), cotton, and labels.

II.3 Research procedure

The research process is as follows:

II.3.1 Preliminary research

Mangoes are sorted, and then those that are not rotten or injured are selected for this research. The mango is then graded according to its maturity level. Following that, the Zero Energy Cool Chamber (ZECC) is chemically sterilized by spraying 0.5 percent chlorine + 70% alcohol. After that, the mangoes are prepared and washed using water, detergent, and $\text{Ca}(\text{OH})_2$ in accordance with the treatment method. After washing, mangoes were air-dried and then stored in two different conditions: ZECC and room temperature.

After that, the mango fruit was observed daily for changes until the eighth day of storage.

II.3.2 Main research

The following stage is mango that has received the best treatment during the washing process (1 percent detergent + 0.5 percent $\text{Ca}(\text{OH})_2$), combined with post-harvest technology, specifically packaging techniques utilizing Polypropylene (PP) plastic, and then returned to the sterilized ZECC. Each day, the fruit is analyzed for damage, which is defined as shriveling, softening, dull skin color, the appearance of black spots on the fruit's skin, and the presence of mold at the fruit's base.

II.4 Research design

The design of the research is divided into two stages. The first stage is to determine the optimal treatment for washing mangoes using various washing ingredients, with the following treatments:

A₀ : Control (Without washing)

A₁ : Water-based cleaning

A₂ : 1% detergent + 0.25 % $\text{Ca}(\text{OH})_2$

A₃ : 1% detergent + 0.5% $\text{Ca}(\text{OH})_2$

Following with storage in ZECC and at room temperature, Physical parameters of the fruit skin surface, color, sap, and impurities were observed visually.

Commented [U8]: ???

Commented [U9]: Put article the before mangoes

Commented [U10]: Put space

The next step is, mango that received the best treatment during the washing process, combined with packaging techniques utilizing Polypropylene (PP) plastic. It is then analyzed every three days using a variety of observation parameters

II.5 Data analysis

The data obtained in the second phase of the study were compiled using a completely randomized design (CRD) with a factorial pattern, namely factor A (type of storage) and factor B (packaged and unpackaged). The research was carried out with three replications.

Data processing used quantitative descriptive method, all parameters were analyzed by analysis of variance (ANOVA) with three replications. The differences for each treatment were further tested using Duncan's test. The software used for data processing is Microsoft Excel 2016 and IBM SPSS Statistics Version 23.

II.6 Observation Parameter

Observation parameters in stage 1 are physical parameters of fruit skin surface, color, sap and dirt. Parameters observed in stage 2 include vitamin C, pH value, water content, total acid, total dissolved solids, weight loss, skin color, hardness test, total microbe, and organoleptic test using 15 panelists.

III. RESULT AND DISCUSSION

III.1 First Phase of Research

The results of the storage of mangoes from the preliminary study showed that mangoes stored at ZECC had better physical quality (visually) than mangoes stored at room temperature. Mangoes stored in ZECC had smoother skin, less noticeable skin discoloration until the 8th day of storage, fewer lenticel spots, and did not grow fungus on the skin surface. The fruit that was stored at room temperature with a rougher skin surface (wrinkled), slightly noticeable skin discoloration, lenticel spots began to appear on the 5th day of storage, as well as fungal growth in some mango samples. These results indicate that storage using the ZECC method is good for extending the shelf life of mangoes compared to storage at room temperature.

III.1.1 Mango Skin Surface

Visual observations of the mango skin's surface revealed that ZECC storage was better compared to room temperature storage. Mango fruits stored in ZECC had smoother skin (not wrinkled) than mango fruits stored at room temperature, which had wrinkled skin surface. The absence of wrinkles in mangoes stored at ZECC is due to the relative humidity (RH) in a good storage room, which is between 80% and 98.04 percent, as opposed to room temperature, which has a relative humidity of 50% to 56.90 percent. This is consistent with Muchtadi (1992), who states that all varieties of mango are susceptible to cold damage in the form of dark spots, uneven ripening, and failure to produce adequate flavor and color, and that a relative humidity of 85-90 percent is required to prevent wilting and softening of various fruits and vegetables (Muchtadi 1992).

The room temperature is higher than the temperature in the ZECC. ZECC has a temperature range of 24-25°C, while the ambient temperature ranges from 26-31°C. Mango fruit stored at room temperature transpired and respired at a faster rate than mango stored in ZECC, causing the mango skin to wrinkle. Because respiration rate is related to the rate of quality deterioration, it can be used to estimate the shelf life of fruit after harvest. As stated by Rizkia (2004) that the slower the rate of respiration, the longer the fruit can be stored in its fresh state; conversely, the faster the rate of respiration, the shorter the shelf life (Rizkia 2004).

III.1.2 Skin color

Mangoes are generally observed visually by observing how clearly the color change from green to yellow appears on the mango skin. Mangoes stored at room temperature and in ZECC without treatment/washing (control), as well as those washed with water and detergent + Ca(OH)₂ exhibited no discernible color changes. On the sixth day of observation, the color changed to a slight

Commented [U11]: Double space ??

Commented [U12]: Put space

Commented [U13]: Put space

Commented [U14]: Put space

yellow hue. This color change occurs because mangoes, as climacteric fruits, accelerate the ripening process during storage. The maturation process that occurs concurrently with the breakdown of chlorophyll, resulting in the appearance of other color pigments such as yellow and red, causing the green color to degrade. This is in line with El-Zeftawi *et al.*, (1988), who stated that the level of chlorophyll content in green fruit decreases during the storage, other pigments begin to appear, turning the fruit yellow or orange (El-Zeftawi *et al.* 1988).

Commented [U15]: ??

Commented [U16]: ??

III.1.3 Sap and Dirt

For mango fruit washed with water, on day 6 DAW (day after washing), there were still remnants of sap attached to the surface of the mango fruit skin, although they were not particularly noticeable. However, there were a few lenticel spots and a change in color at the fruit's base on day 6 DAW (day after washing) until the 8th day of DAW. While mangoes treated with 1% detergent + 0.25 percent $\text{Ca}(\text{OH})_2$ can visually remove sap, the treatment was more effective at 1% + $\text{Ca}(\text{OH})_2$ 0.5 percent detergent immersion, which resulted in samples of mango fruit being more free of sap and dirt, resulting in a smoother surface with no noticeable changes up to 8 DAW. This is because 1% detergent binds to oil and effectively removes or lifts dirt. Until the eighth day after DAW mango was treated with 1% detergent and 0.5 percent $\text{Ca}(\text{OH})_2$, no lenticel or fungal spots appeared at the base or on the surface of the fruit skin. The surface is smoother and burn-free because the detergent's surfactant active ingredients can remove the oil contained in the sap. Alkaline $\text{Ca}(\text{OH})_2$ solution can neutralize the acid in the sap attached to the golek mangocultivar's skin. This is consistent with Ahmad, S *et al.* (2017)'s finding that the 1% + $\text{Ca}(\text{OH})_2$ 0.5 percent detergent treatment resulted in a lower mean score for reducing lenticel spots at 2 to 14 DAW when compared to the control (Ahmad *et al.* 2017). In accordance with Taqiyah (2015), a combination of detergent and $\text{Ca}(\text{OH})_2$ is capable of removing sap and oil from the surface of the Gedong mango skin (Taqiyah 2015).

Commented [U17]: ???

III.2 Second Phase of Research

The second stage of this study involved determining the quality and shelf life of mangoes while they were stored. Mangoes that received the best washing treatment (1 percent detergent + 0.5 percent $\text{Ca}(\text{OH})_2$) were then given packaging treatment (using Polypropylene (PP) plastic and without packaging) and then analyzed for quality. Mangoes packaged with Polypropylene (PP) plastic can be stored in ZECC for 21 days, whereas mangoes packaged without Polypropylene plastic have a shelf life of only 18 days.

Commented [U18]: Put space

III.2.1 Weight Loss

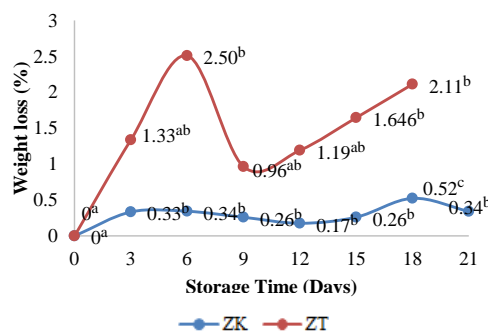


Figure 1. The weight loss of Mangoes During Storage. Values followed by different letters indicate treatment results that are significantly different ($p < 0.05$).

During storage, the mango fruit's weight loss tends to increase. Unpackaged mangoes (ZT) lost approximately twice as much weight as packaged mangoes (ZK). This means that when packaging is used in combination with the ZECC storage technique, mangoes lose less weight. Unpackaged mangoes experienced a greater increase in weight loss due to a high evaporation rate (transpiration), whereas packaged mangoes experienced less water evaporation during storage. Water loss results in withering and shrinking. This is consistent with Winarno (2002), who states that the amount of

water in foods determines their freshness, appearance, and durability (Winarno 2002). If some of the water in the food evaporates, weight loss occurs, reducing the food's freshness, appearance, and durability.

In addition to transpiration, weight loss is also influenced by the respiration process of mango fruit. Carbon loss can occur during the respiration process. Carbon compounds contained in the sugar in mangoes will bind and react with oxygen which will produce simple volatile compounds, namely water vapor and carbon dioxide so that the fruit will lose its weight. So in this case it is known that the respiration process can be suppressed by a combination of packaging and storage in ZECC. This is in accordance with the opinion of Syafutri et al., (2006), which states that the process of fruit respiration can be suppressed by combining packaging and storage at low temperatures (Syafutri, Pratama, and Saputra 2006).

III.2.2 Hardness Level

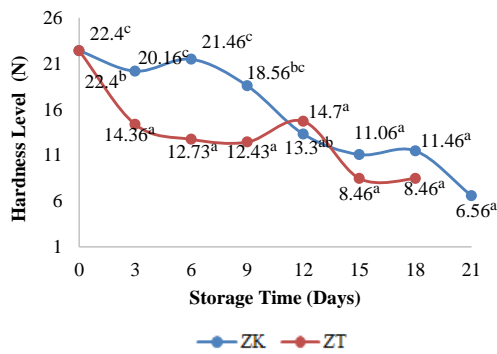


Figure 2. The Hardness Level of Mango Fruit During Storage. Values followed by different letters indicate treatment results that are significantly different ($p < 0.05$).

The ripening process of mangoes during storage results in changes in the level of mango fruit hardness. The ripening process in mangoes occurs concurrently with the conversion or degradation of protopectin to pectin, resulting in a decrease in cell wall rigidity. Mangoes without packaging treatment (ZT) had a greater loss of hardness than mangoes with packaged treatment (ZK). This is due to the fact that unpackaged mangoes have a higher respiration rate and a higher enzyme activity. The more actively these enzymes are, the softer the texture of the fruit. Meanwhile, the rapid rate of respiration causes the fruit tissue to rupture, resulting in the mango becoming soft. The mango with packaging treatment (ZK) can reduce the amount of oxygen received, thereby slowing the respiration process (maintained). This is consistent with Syafutri et al. (2006), who state that the decrease in hardness is also a result of the respiration and transpiration processes (Syafutri et al. 2006). The respiration process results in the breakdown of carbohydrates into simple compounds and tissue rupture, resulting in the mango becoming soft, whereas the transpiration process results in water evaporation, resulting in the mango becoming wilted.

Commented [U19]: addspace

Commented [U20]: states

III.2.3 Vitamin C levels

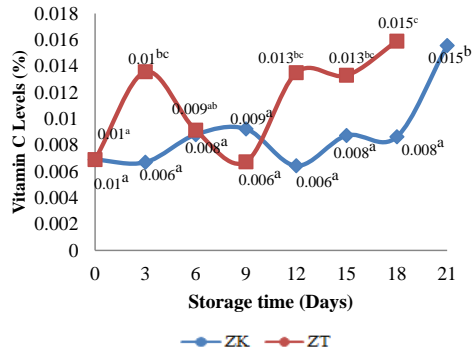


Figure 3. Vitamin C Levels of Mangoes During Storage. Values followed by different letters indicate treatment results that are significantly different ($p < 0.05$).

The levels of vitamin C (ascorbic acid) of mangoes during storage in ZECC tend to vary, both packaged in polypropylene plastic and mangoes without packaging. The significant increase in vitamin C levels of unpackaged mangoes until the end of storage was in line with the faster ripening process of mangoes compared to packaged mangoes. This is in accordance with Pantastico (1986), which states that ripe fruit will increase in acidity, and this increase occurs simultaneously with the climacteric pattern, while vitamin C levels will decrease when the maximum point of increase has been exceeded (withering stage)(Pantastico 1986). The ripening process of unpackaged mangoes is faster because the respiration process is greater than that of packaged mangoes. Mango packaging can regulate/minimize the respiration process of the fruit so that the freshness of the mango can be maintained. This is in accordance with Park et al., (2004), which states that Polypropylene (PP) plastic has high permeability properties which can regulate the rate of atmospheric absorption or respiration rate which can maintain fruit freshness longer(Park, Kim, and Yun 2004). The results of analysis of variance showed that mango without packaging treatment and mango with packaging treatment had a significant effect on vitamin C levels during storage. This is indicated by the value of vitamin C which was initially low and then increased until the end of storage. The increase or decrease in vitamin C is because the vitamin is unstable, easily oxidized when exposed to air (oxygen) and this process can be accelerated by storage temperature. This is in accordance with Tannenbaum (1976), stating that the reduction of O_2 will inhibit the degradation of ascorbate into dehydroascorbic acid and H_2O_2 (Tannenbaum 1976). The resulting H_2O_2 will cause autoxidation so that it will increase the damage of vitamin C.

III.2.4 Total Acid

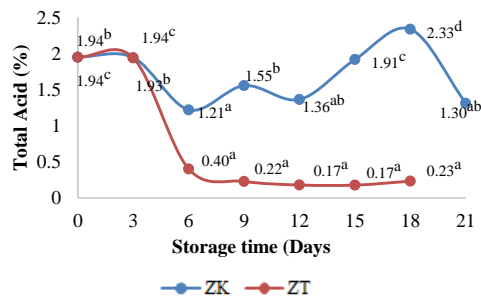


Figure 4. Total Acid Level of Mango Fruit During Storage. Values followed by different letters indicate treatment results that are significantly different ($p < 0.05$).

The total acid value of mango in ZECC storage, both packaged and unpackaged, tends to decrease, though the trend is variable. The percentage of total acid in the fruit decreases as the fruit is stored. The decrease in the percentage of total acid is due to the respiration process's use of organic acids, as well as the use of organic acids by microbes in energy-consuming activities. This energy is obtained through the breakdown of the nutrients found in food. Organic acids are converted to sugars during the respiration process. Amalya et al. (2017) found in their research that the fruit's decreased organic acid value indicated that the fruit's ripening metabolism was functioning normally (Khairi, Falah, and Pamungkas 2017).

Commented [U21]: Should be added reference

Total acid in mangoes that were not packaged (ZK) contained a greater proportion of total acid or degraded more rapidly than in packaged mangoes (ZK). This is due to the respiration process of unpackaged mangoes. Merynda et al. (2006) state that when mangoes are not packaged, the respiration process cannot be minimized due to the abundant O₂ in the environment (Syafutri et al. 2006).

Commented [U22]: I think this sentence need to be deleted

III.2.5 Total Dissolved Solids (TDS)

Mangoes' total dissolved solids (packaged and unpackaged) exhibit a fluctuating graph. Unpackaged mangoes (ZT) underwent a maximum ripening process, as indicated by the percentage of TDS value increasing significantly at first and then gradually decreasing until the end of storage. The increase in TDS is a result of starch hydrolysis during ripening process. While the decrease in TDS occurs as a result of the abundant O₂ available in the environment, which prevents the respiration process from being suppressed. Thus, glucose as the result of starch hydrolysis then was consumed during the respiration process, resulting in a rapid decrease in the sugar content of the fruit. Pantastico (1993) confirms this by stating that during ripening, starch is hydrolyzed into simple compounds that serve as a source of energy during the respiration process (Pantastico 1986). At this point, the sucrose has been converted back to glucose and fructose. The decrease in total sugar content of unpackaged mangoes occurred as the mango fruit began to ripen, at which point the starch content began to decrease and the activity of the invertase enzyme decreased, resulting in a decrease in sugar content. The mango with packaging (ZK) has the ability to maintain the fruit's ripening process, as indicated by the predominant fluctuating TDS value. This demonstrates that by combining packaging and storage in ZECC, the rate of decrease in the percentage of TPT in mangoes can be slowed.

Commented [U23]: It may be which contributes to the respiration process

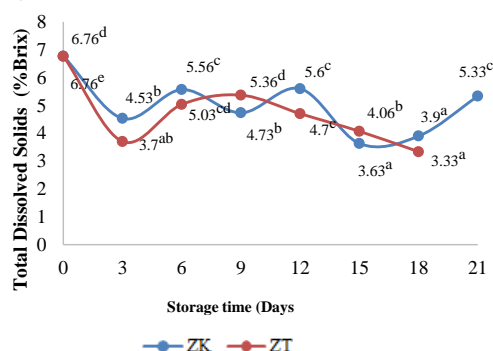


Figure 5. Total Dissolved Solids of Mango Fruit During Storage. Values followed by different letters indicate treatment results that are significantly different ($p < 0.05$).

This variable total dissolved solids value is also a result of the fruit's non-uniform maturity level. Non-uniform fruit ripeness causes abnormal respiratory activity so that the breakdown process of simple sugars varies. In general, changes in total dissolved solids content increased at the maximum point of storage and then decreased until the fruit began to rot on the final day of storage. This is consistent with Biale and Young's (1971) observation that the general trend is for a rapid increase in sugar content followed by a decline; in climacteric fruit, this condition becomes a marker (Biale and Young 1971).

III.2.6 Degree of Acidity (pH)

According to the graph, mango fruit are acidic, with a pH value ranging between 2 and 6 during storage. The ripening of mangoes alters the pH value of the fruit. Without packaging treatment (ZT), mangoes ripened rapidly (maximum), increasing the pH value. It is not the case with packaged mangoes (ZK), as their ripening process is slowed, resulting in a stable pH value throughout storage. As the mango ripens, the acid content decreases while the simple sugars increase, as indicated by the decrease in total acid content. The pH value is directly proportional to vitamin C levels and inversely proportional to total acidity, as shown in the graph. This is consistent with Amalya et al., (2017), who state that changes in pH indicate changes in the composition of the fruit's cell fluid as it matures; the pH value that tends to be high is related to relatively high ascorbic acid (vitamin C) levels during storage; this change indicates that the fruit's metabolism affects the pH value (Khairi et al. 2017).

Commented [U24]: Add space

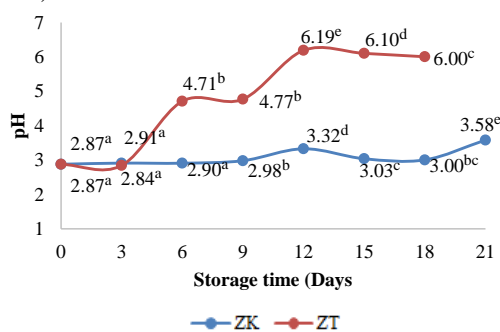


Figure 6. pH Value (Degree of Acidity) Mango Fruit During Storage. Values followed by different letters indicate treatment results that are significantly different ($p < 0.05$).

III.2.7 Water content

The water content of mangoes stored in the ZECC method varied slightly during storage. When compared to unpackaged mangoes, packaged mangoes (ZK) are able to maintain changes in water content during storage. This is because PP packaged mangoes have a high permeability, which minimizes changes in water content during storage. This is consistent with Schwartz (2009), who states that because of the packaging, ambient air cannot easily enter the material, thereby inhibiting the process of water exchange during storage (Schwartz 2009).

Commented [U25]: High or low ?????

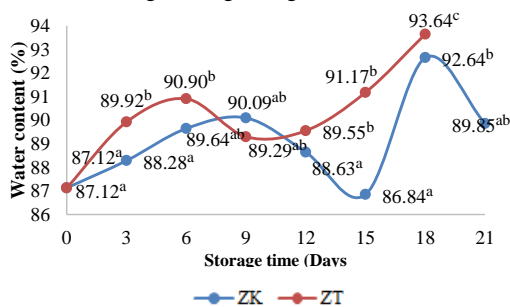


Figure 7. Water Content of Mangoes During Storage. Values followed by different letters indicate treatment results that are significantly different ($p < 0.05$).

Due to the high humidity in ZECC storage, which reached 80-90 percent, mango fruit experienced an increase and decrease in water content during storage. Due to the high humidity level in the ZECC room, moisture absorption from the environment into the stored mango is possible. The longer the storage time, the higher the water content will remain. According to Herawati (2008), a significant factor influencing the decline in the quality of food products is changes in the product's water content, which can be influenced by the room's temperature and humidity during storage (Herawati 2008). This opinion is backed up by Retnani et al., (2009), who state that the high

Commented [U26]: Add space

humidity of the storage room can result in the absorption of water vapor from the air into the foodstuffs, resulting in an increase in water content (Retnani et al. 2009).

Additionally, the increase in water content during storage is a result of the mangoes' respiration process. During storage, the fruit undergoes a ripening process that includes the conversion of starch to simple sugars ($C_6H_{12}O_6$). These simple sugars then interact with the oxygen (O_2) in the chamber, increasing the rate of water (H_2O) formation in the fruit. This is consistent with Nurhayati S (2004), who states that one of the causes of changes in the water content of fruit is the respiration process, during which water is formed as a result of sugar reorganization into simpler compounds.

III.2.8 Color

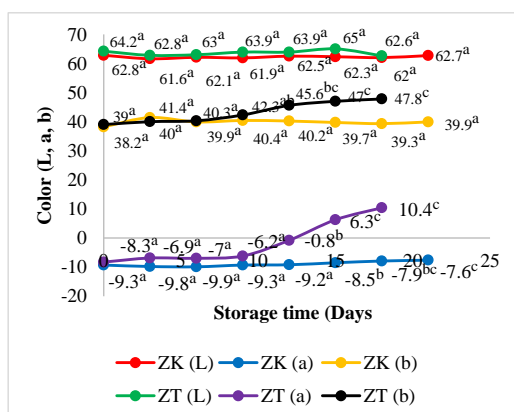


Figure 8. Analysis of Mango Skin Color During Storage. Values followed by different letters indicate treatment results that are significantly different ($p < 0.05$).

The L^* value indicates the brightness level of the mango fruit, which indicates the reflected light that produces achromatic colors of white, gray and black, ie from a value of 0 (black) – 100 (white). The L^* value of unpackaged and packaged mangoes had a very small decrease in lightness value during storage. The range of changes in the L^* value from 65-62 indicates a slight decrease in brightness level during storage. The longer the fruit is stored, the lower the brightness level of the mango. According to Ahmad et al., (2014), that the brightness level of the color will decrease which will be directly proportional to the longer the shelf life, the fruit will lead to spoilage in the end (Ahmad, Darmawati, and Refilia 2014). The decreasing brightness level of the mango skin color is caused by changes in the chlorophyll content of the fruit. This is in accordance with the statement of Syafutri et al., (2006), which states that the reduced level of color brightness in fruit during storage is caused by reduced chlorophyll content in fruit skins and the appearance of carotenoids (Syafutri et al. 2006).

The a^* value is a value that shows the gradation of green to red. A mixed red-green chromatic color with a value of $+a^*$ (positive) from 0 to +80 for red and a value of $-a^*$ (negative) from 0 to -80 for green. The a^* value of mango tends to increase during the storage process. Mangoes tend to be green, indicated by an a^* value below 0, but the longer the storage time, the color of the fruit moves to red. The significant increase in a^* value was caused by the high respiration rate of unpackaged mangoes so that the degradation of chlorophyll was also rapid which had the effect of accelerating the synthesis of pigment (color change) of the fruit. This is in accordance with the opinion of Masfufatun et al. (2015), which states that a high respiration rate will also cause chlorophyll degradation and pigment synthesis to be fast, consequently accelerating color changes (Masfufatun, Kumala, and Rahayuningsih 2009).

The b^* value indicates the color gradation to yellow. A mixed blue-yellow chromatic color with a $+b^*$ (positive) value from 0 to +70 for yellow and a $-b^*$ (negative) value from 0 to -70 for blue. Based on the graph above, it shows that unpackaged mangoes have a slowly increasing b^* value during storage compared to packaged mangoes whose b^* values tend to be stable until the

end of storage. The results of the measurement of the b^* value show that the longer the storage, the yellow color of the mango will be clearer. The increasing b^* value in unpackaged mangoes indicates that the fruit is getting more mature than the packaged mangoes during storage. This is in accordance with the statement of Kusumiyati et al., (2018), which states that the longer the storage, the yellow color of the mango is more clearly marked by the higher the mean b^* value. The higher the b^* value in the mango can be indicated the higher the ripeness level of the fruit (Kusumiyati et al. 2018).

III.2.9 Organoleptic test

III.2.9.1 Color

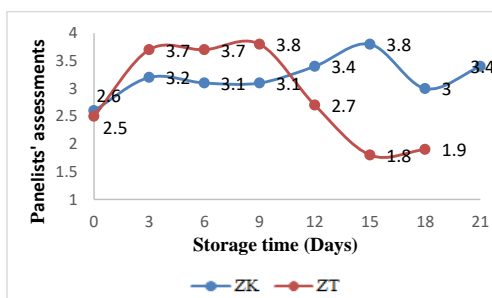


Figure 9. Results of Organoleptic Testing on Mango Color in ZECC Storage

The changes in panelists' assessments of organoleptic color parameters in mangoes were due to the nature of mangoes undergoing post-harvest ripening (after harvesting), specifically that the color will change during the storage process due to chlorophyll degradation into other pigments. The panelists' assessment of mangoes with packaging treatment (ZK) tended to remain stable until the end of storage, with an average value of 3 (slightly similar), whereas mangoes without packaging (ZT) maintained an average value of 4 (similar) until the ninth day of storage, when it decreased until the end of storage. This demonstrates that mangoes treated with packaging can help preserve or delay the color change of mangoes stored in ZECC. Packaging treatment on mangoes can slow the respiration process, resulting in a slower color change and maturation and aging process. This is consistent with Kamilia (2017), who states that a faster respiration rate can accelerate the senescence process, which results in a more rapid color change.

Commented [U27]: Add space

III.2.9.2 Aroma

The panelists' evaluations of the mango aroma parameters revealed a range of results but a consistent pattern of increasing and then decreasing until the end of storage. In terms of fruit aroma, panelists prefer the unpackaged aroma of mango fruit.

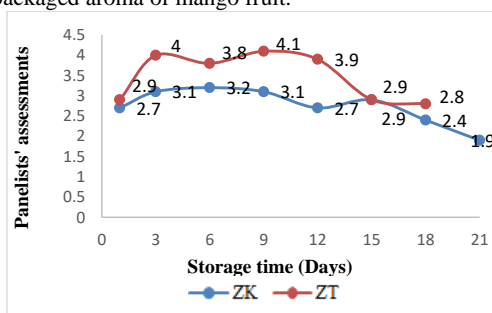
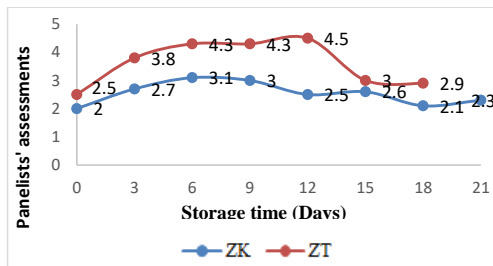


Figure 10. Results of Organoleptic Testing on Mango Aroma in ZECC Storage

The high acceptance of unpackaged mango aroma (ZT) is a result of the increasing ripening process (perfect ripening), which results in an increase in the production of volatile components.

While the packaged mango (ZK) took longer to decompose, the panelists generally disliked it due to the incomplete ripening process, which resulted in a low flavor. This is consistent with Muchtadi (1992), who stated that ripening typically results in an increase in the content of simple sugars, which imparts a sweet flavor, as well as an increase in the production of volatile substances, which imparts a distinctive fruit flavor.

III.2.9.3 Taste



Gambar 11. Results of Organoleptic Testing on Mango Taste in ZECC Storage

The results of organoleptic tests on mangoes stored at ZECC showed that the panelists' assessment of fruit taste increased and then decreased until the end of storage. The range of values between 3-5 (based on the graph) shows that the panelists' assessment of unpackaged mangoes (ZT) is dominantly preferable to mangoes with packaged treatment (ZK) with a value of 2-3. The high rating for unpackaged mangoes is because the mangoes undergo an even ripening process during storage, resulting in a distinctive taste and good color which are preferred by panelists (Ali 2017). The sweet taste is due to the change in the starch content of the fruit to sugar during storage. This is in accordance with the statement of Mulyati (2012), that changes during the ripening process are changes in starch and fat reserve materials into various sugars (Mulyati 2012). The mango with packaging (ZK) undergoes a slow ripening process due to its low respiration rate in the presence of packaging, but it takes longer to decay or damage in ZECC storage.

IV.2.9.4 Texture

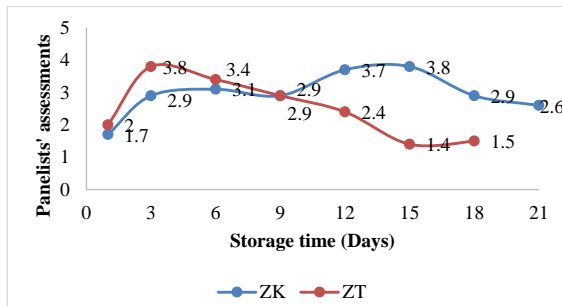


Figure 12. Results of Organoleptic Testing on Mango Texture in ZECC Storage

Panelists determined that mango with packaged treatment (ZK) (mean value 3-4) was preferable in terms of texture because the level of hardness did not decrease significantly (soft), as opposed to mango without packaged treatment (ZT) (mean value 2-3). The texture began as hard, which the panelists disliked, then softened slightly, which the panelists liked, and finally became extremely soft due to damage/rotting, which the panelists disliked. When the qualitative (organoleptic test of texture parameters) analysis of mango fruit is combined with quantitative analysis (with a penetrometer), it is discovered that the level of hardness (the process of hardness decreasing) is directly proportional during storage.

Mangoes' softening texture is caused by the ripening process that occurs during storage. Maturation occurs concurrently with the conversion or degradation of insoluble protopectin

Commented [U28]: Add space

to soluble pectin. The reshuffle occurs as a result of the action of enzymes such as pectin methyl esterase, which softens the fruit. Proteopectin levels in the fruit decrease as the fruit ripens, while pectin levels increase. This is in accordance with Afrazak et al., (2014), that as fruit ripens and stores, some of the water-insoluble protopectin converts to water-soluble pectin, reducing the cohesion of the cell walls that connect cells, resulting in a decrease in texture or fruit hardness and the fruit becoming soft (Johansyah and Kusdiantini 2014). Additionally, the rate of respiration has an effect on the degree of hardness or texture. Unpackaged mangoes with a high respiration rate cause the fruit's tissue to rupture and enzyme activity to accelerate, resulting in a softer fruit texture. The mango with packaging treatment (ZK) can reduce the amount of oxygen received, thereby slowing the respiration process (maintained).

III.2.10 Microbial Analysis (Yeast Mold Count)

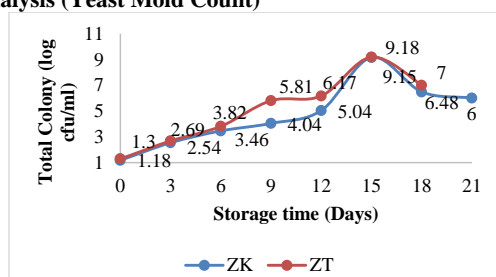


Figure 13. Mold and Yeast cell count on Mangoes During Storage in ZECC

According to the graph, the results of microbial analysis (mold and yeast counts) on mango fruit storage in ZECC indicated that yeast mold growth continued to increase and then decreased gradually until the end of storage. Microbial growth (mold and yeast) that began low/small and then increased to a maximum growth peak on the 15th day generally indicated that the mangoes' quality deteriorated during storage and gradually entered the senescence phase. This also demonstrates that mangoes with a relatively high sugar content and a low pH provide an ideal environment for molds and yeasts to grow to their maximum growth capacity during storage. This is consistent with Seema R (2015) statement that fruit with a high sugar content and a low/acidic pH (pH range between 3-8) promotes the growth of fungi (mold/yeast) after the fruit is harvested (Rawat 2015).

Mango without packaging (ZT) exhibited a greater increase in the growth of the dominant mold/yeast than mango with packaging (ZK). This demonstrates that by combining calcium hydroxide washing with packaging on mangoes stored in ZECC, the rate of microbial growth can be slowed or suppressed, thereby extending the fruit's life phase. Certain microbes require oxygen to grow, which can be suppressed through packaging. This is consistent with the opinion of Ira M et al. (2017), who state that treating fruit with packaging technology can suppress the air activity required by microbes, thereby slowing the growth rate of pathogenic microbes (Mulyawanti, Syaefullah, and Amiarsi 2018).

IV. Conclusions

It can be concluded that analysis of the quality of golek mango (*Mangifera indica* L.) physically, chemically, microbiologically, and sensory in the Zero Energy Cool Chamber (ZECC) storage technique shows that ZECC can maintain optimal fruit quality through a washing treatment process (chemically) in combination with packaging. In addition, the Zero Energy Cool Chamber (ZECC) storage method with a combination of washing and packaging treatments is effective in maintaining the quality of mangoes up to 21 days of storage.

V. Acknowledgment

This research was funded by the Directorate General of Research and Development, Ministry of Research, Technology and Higher Education, Republic of Indonesia, through LPPM Unhas : Penelitian Terapan 2020.

Commented [U29]: Should be added contract number

References

- Ahmad, Sutopo, Roedhy Poerwanto, and Suryo Wiyono. 2017. "Keefektifan Bahan Pencuci Dan Pencegah Penyakit Terhadap Kualitas Buah Mangga CV. Gedong Gincu Dan Arumanis (The Effectiveness of Washing Materials and Disease Protecting Agent on the Quality of Mango Fruit Cv. Gedong Gincu and Arumanis)." *Jurnal Hortikultura* 27(2):253–60.
- Ahmad, Usman, Emmy Darmawati, and Nur Rahma Refilia. 2014. "Kajian Metode Pelilinan Terhadap Umur Simpan Buah Manggis (Garcinia Mangostana) Semi-Cutting Dalam Penyimpanan Dingin." *Jurnal Ilmu Pertanian Indonesia* 19(2):104–10.
- Ali, Kamilia Nur Yaumil. 2017. "Mutu Buah Mangga (Mangifera Indica L.) Dan Tomat (Lycopersicum Esculentum Mill.) Yang Disimpan Pada ZECC (Zero Energy Cool Chamber)." Universitas Hasanuddin.
- Biale, J. B. and R. Young. 1971. *The Avocado Pear. Dalam Hulme, A.C. The Biochemistry of Fruit and Their Produce*. London: Academic Press.
- Dirpan, A. 2019. "The Quality of Tomato (Lycopersicum Esculentum Mill.) Stored on ZECC (Zero Energy Cool Chamber)." P. 12012 in *IOP Conference Series: Earth and Environmental Science*. Vol. 270. IOP Publishing.
- Dirpan, Andi. 2008. *ZECC (Zero Energy Cool Chamber) Penyimpanan Dingin Yang Murah Dan Ramah Lingkungan Untuk Memperpanjang Masa Simpan Buah Dan Sayur Setelah Panen*. Makassar: Universitas Hasanuddin.
- Dirpan, Andi, Muhammad Tahir Sapsal, Abdul Kadir Muhammad, Mulyati M. Tahir, and Rahimuddin. 2017. "Evaluation of Temperature and Relative Humidity on Two Types of Zero Energy Cool Chamber (ZECC) in South Sulawesi, Indonesia." *IOP Conference Series: Earth and Environmental Science* 101:012028.
- El-Zeftawi, B. M., L. Brohier, L. Dooley, F. H. Goubran, R. Holmes, and B. Scott. 1988. "Some Maturity Indices for Tamarillo and Pepino Fruits." *Journal of Horticultural Science* 63(1):163–69.
- Herawati, Heny. 2008. "Penentuan Umur Simpan Pada Produk Pangan." *Jurnal Litbang Pertanian* 27(4):124–30.
- Islam, M. P. and T. Morimoto. 2015. "ScienceDirect Evaluation of a New Heat Transfer and Evaporative Design for a Zero Energy Storage Structure." *Solar Energy* 118:469–84.
- Islam, M. P., T. Morimoto, and K. Hatou. 2013. "Dynamic Optimization of inside Temperature of Zero Energy Cool Chamber for Storing Fruits and Vegetables Using Neural Networks and Genetic Algorithms." *Computers and Electronics in Agriculture* 95:98–107.
- Johansyah, Afrazak and Endang Kusdiantini. 2014. "Pengaruh Plastik Pengemas Low Density Polyethylene (LDPE), High Density Polyethylene (HDPE) Dan Polipropilen (PP) Terhadap Penundaan Kematangan Buah Tomat (Lycopersicon Esculentum. Mill)." *Anatomi Fisiologi* 22(1):46–57.
- Khairi, Amalya Nurul, Affan Fajar Falah, and Agung Putra Pamungkas. 2017. "Analisis Mutu Pascapanen Melon (Cucumis Melo L.) Kultivar Glamour Sakata Selama Penyimpanan." *CHEMICA: Jurnal Teknik Kimia* 4(2):47–52.
- Kusumiyati, Kusumiyati, Farida Farida, Wawan Sutari, and Syariful Mubarak. 2018. "Kualitas Buah Mangga Selama Penyimpanan Pada Keranjang Anyaman Bambu Dengan Identifikasi

- Ruang Warna L*, A* Dan B.” *Kultivasi* 17(2):628–32.
- Masfufatun, Widaningsih, N. Kumala, and T. Rahayuningsih. 2009. “Pengaruh Suhu Dan Waktu Penyimpanan Terhadap Vitamin c Dalam Jambu Biji (Psidium Guajava).” *Universitas Wijaya Kusuma, Surabaya*.
- Muchtadi, Deddy. 1992. *Fisiologi Pasca Panen Sayuran Dan Buah-Buahan: Petunjuk Laboratorium*. Institut Pertanian Bogor.
- Mulyati. 2012. *Sayur-Sayuran, Buah-Buahan Penanganan Dan Pengolahannya*. Makassar: CV. Indo media.
- Mulyawanti, Ira, Enrico Syaefullah, and Dwi Amiarsi. 2018. “Teknologi Pengemasan Atmosfir Termodifikasi (Modified Atmosphere Packaging/Map) Dan Vakum Pada Buah Durian.”
- Pantastico, E. B. 1986. *Fisiologi Pascapanen, Penanganan Dan Pemanfaatan Buah-Buahan Dan Sayur-Sayuran Tropika Dan Subtropika (Terjemahan Kamariyani 1997)*. Yogyakarta: Gajah Mada University Press.
- Park, T., Y. A. Kim, and J. Yun. 2004. “The Need for Collaboration in the Supply Chain For Successful Direct Shipments.” in *Proceedings of the Thirty-Third Annual Meeting of the Western Decision Sciences Institute*.
- Rawat, Seema. 2015. “Food Spoilage: Microorganisms and Their Prevention.” *Asian Journal of Plant Science and Research* 5(4):47–56.
- Retnani, Y., W. Widiarti, I. Amiroh, L. Herawati, and K. B. Satoto. 2009. “Daya Simpan Dan Palatabilitas Wafer Ransum Komplit Pucuk Dan Ampas Tebu Untuk Sapi Pedet.” *Media Peternakan* 32(2):130–36.
- Rizkia. 2004. “Kajian Laju Respirasi Dan Perubahan Mutu Buah Mangga Gedong Gincu Selama Penyimpanan Dan Pematangan Buatan.” Institut Pertanian Bogor.
- Schwartz, Naomi. 2009. “Pengaruh Jenis Bahan Pengemas Terhadap Kualitas Cabe Merah Segar Selama Penyimpanan Dingin.” Universitas Sumatra Utara.
- Syafutri, Merynda I., F. Pratama, and D. Saputra. 2006. “Sifat Fisik Dan Kimia Buah Mangga (*Mangifera Indica* L.) Selama Penyimpanan Dengan Berbagai Metode Pengemasan.” *Jurnal Teknologi Dan Industri Pangan* 17(1):1–11.
- Tannenbaum. 1976. *Vitamins and Mineral*. New York (US: Mercel Dekker).
- Taqqiyah, Affifah. 2015. “Pengaruh Penambahan Fungsida Pada Bahan Pencuci Serta Suhu Penyimpanan Terhadap Peningkatan Kualitas Mangga. (*Mangifera Indica* L.)”
- Winarno. 2002. *Fisiologi Lepas Panen Produk Hortikultura*. Bogor: M-Brio Press.

Revised version received

Andi Dirpan <dirpan@unhas.ac.id> Oct 6, 2021, 4:02 PM

to ram

Dear Dr. Ram Kishan
Chief-Editor,IJASS

Hope this email finds you well.

First and foremost, I would like to warmly appreciate you, and your specialist reviewers, for your time and consideration on the evaluation of our manuscript.

On behalf of the authors, I believe that our manuscript (manuscript number: **8072**) was concisely reviewed by the most knowledgeable and resourceful reviewers of your journal.

For Peer Review

In the attachment, you see all of the comments and responses. Also, we attached the file revision as requested by the reviewer. Hope these explanations and responses are enough to meet the criteria for eligibility for possible publication.

Sincerely yours.
Dr. Andi Dirpan
Corresponding author

Dear Dr. Ram Kishan
Chief-Editor,IJASS

Hope this email finds you well.

First and foremost, I would like to warmly appreciate you, and your specialist reviewers, for your time and consideration on the evaluation of our manuscript.

On behalf of the authors, I believe that our manuscript (manuscript number: **8072**) was concisely reviewed by the most knowledgeable and resourceful reviewers of your journal.

For Peer Review

In attachment, you see all of the comments and responses. Also, we attached file revision as requested by reviewer.

Hope these explanations and responses are enough to meet the criteria for eligibility for possible publication.

Sincerely yours.
Dr. Andi Dirpan
Corresponding author

Reviewers' Comments to the Author:

Reviewed #8072

Review:

Change with : This study aimed

Thanks for the comment. We have revised it in abstract

I recommend modifying the keywords, eliminate those that are in the title, and replace them by others to promote and give more information about your work

Thanks for the comment. We have replaced the key words

No need to put this

Thanks for the comment. We have revised it

Add space

Thanks for the comment. We have added it

Be consistent post-harvest or postharvest ??

Thanks for the comment. We have revised it

Put space

Thanks for the comment. We have added it

???

We have revised it

Put article the before mangoes

We have revised it

Put space

We have revised it

Put space

We have revised it

Put space

We have revised it

Put space

We have revised it

???

We have revised it

???

We have revised it

Put space

We have revised it

states

We have revised it

Should be added reference

Thanks for the comment. We have added it

I think this sentence need to be deleted

We have revised it

It may be which contributes to the respiration process

We have revised it

High or low ?????

We think high

Extending of Mango (*Mangifera Indica* L.) Shelf Life with Combination of Zero Energy Cool Chamber (ZECC) Storage Technology, Washing and Packaging¹⁾

ABSTRACT

Mangoes suffer up to a 20%-50% shrinkage, loss, and quality damage as a result of improper harvest and post-harvest handling, as well as poor storage conditions. The presence of a post-harvest technology system of Zero Energy Cool Chamber (ZECC) storage combined with pre-handling treatment (washing and packaging) is one method of minimizing damage and extending the shelf life of mangoes. This study aimed to determine the mango golek's quality and shelf life by using ZECC in combination with washing and packaging. This study used a completely randomized design (CRD) with factorial patterns, specifically factor A (storage type) and factor B (packaging and without packaging). The study's observation parameters were divided into two stages, with stage 1 consisting of physical parameters and stage 2 consisting of chemical, microbiological, and sensory parameters. According to preliminary research, the best treatment is washing with 1% detergent + 0.5 percent $\text{Ca}(\text{OH})_2$, which results in a smoother skin surface, less noticeable discoloration, and a cleaner surface free of sap and dirt. Physical, chemical, microbiological, and sensory analysis of mango golek (*Mangifera indica* L.) demonstrates that the ZECC storage technique can maintain fruit quality optimally in combination with washing (chemical) and packaging treatment processes, and it can effectively protect the mango golek's quality for up to 21 days.

Keywords: Fruit, Quality, Postharvest

I. INTRODUCTION

Indonesia possesses immense natural resource potential, particularly in horticultural crops like mango. According to the Indonesian Central Statistics Agency, mango production reached 2,431,329 tons per year in 2014 and 2,178,833 tons per year in 2015, a decrease of 10.39 percent. Mango productivity continues to be harmed by improper harvesting and postharvest handling, which degrades the quality of the mangoes. Additionally, storage conditions are insufficient during agricultural product distribution and marketing, resulting in fruit depreciation. According to research conducted in developing countries, improper harvesting and post-harvest handling can result in fruit yield losses ranging from 20% to 50% (Dirpan et al. 2017)

Cold storage is one technique for postharvest handling. However, rural areas, which are typically agricultural centers, have severe shortages of cold storage, such as refrigerators. Additionally, the high operational costs associated with cold storage present a significant barrier to farmers employing post-harvest handlers. Additionally, it produces freon, an environmentally hazardous chemical (Dirpan et al. 2017). In light of the aforementioned issues, we require an energy-free (zero energy) cold storage system that is also affordable (low cost) and environmentally friendly (eco friendly), one of which is the Zero Energy Cool Chamber (ZECC) (Islam and Morimoto 2015).

The Zero Energy Cool Chamber (ZECC) is a cost-effective and environmentally friendly method of storing fruits and vegetables following harvest. Due to the fact that ZECC does not require electricity to operate, it is frequently referred to as an environmentally friendly fruit and vegetable storage system (Dirpan 2019; Islam, Morimoto, and Hatou 2013). Additionally, this storage system is cost effective due to the fact that it makes use of readily available materials such as bricks, sand, plastic roofs, and water (Dirpan et al. 2017; Islam et al. 2013)

Recent years have seen an increase in research on fruit and vegetable storage methods utilizing ZECC, as demonstrated by Kamilia et al. (2017) and Dirpan et al. (2018) studies examining the quality of mangoes and tomatoes stored in ZECC (Ali 2017; Dirpan 2008). However, because fungi grew around the mangoes in the aforementioned studies, ZECC was used in conjunction with pre-handling treatments such as washing and packaging to minimize the possibility of mold and yeast growth and to extend the shelf life of the golek mango. As a result, the purpose of this research were: to determine the physical, chemical, microbiological, and sensory characteristics of mango golek stored in a ZECC (Zero Energy Cool Chamber) in combination with washing and packaging

processes and to determine the shelf life of mangoes stored in a ZECC (Zero Energy Cool Chamber) in combination with washing and packaging processes.

II. Materials and Methods

II.1 Date and Location of Research

This research was conducted from July to November 2019 at the Food Processing Laboratory and the Chemical Laboratory of Food Quality Analysis and Supervision of the Food Science and Technology Study Program, Department of Agricultural Technology, Faculty of Agriculture, Hasanuddin University, as well as at the Research Activity Center (PKP) building and Lecturer Housing Unhas Tamanlarea, Makassar.

II.2 Instruments and materials

The tools used in this research include a zero energy cool chamber (ZECC), polypropylene plastic packaging, fruit racks, temperature and relative humidity sensors, hoses, scales, analytical scales, and moisture, analyzer, colorimeter, penetrometer, digital hand refractometer, pH meter, stirring rod, beaker, erlenmeyer flask, volumetric flask, dropper pipette, volume pipette, petri dish, autoclave, bulb, micropipet, test tube, tube rack, laminar air flow (LAF), plates, spoons, knives, rags, blenders.

Materials used in this study were 77 golek mango (main ingredient) with a maturity index of 2 (light green), aquadest, detergent, chlorine, calcium hydroxide ($\text{Ca}(\text{OH})_2$), sodium hydroxide (NaOH), iodine, indicator phenolphthalein, alcohol, buffer pH 7, mineral water, starch indicator (starch), potato dextrose agar (PDA) medium, inhibitor (chloramphenicol), cotton, and labels.

II.3 Research procedure

The research process is as follows:

II.3.1 Preliminary research

Mangoes are sorted, and then those that are not rotten or injured are selected for this research. The mango is then graded according to its maturity level. Following that, the Zero Energy Cool Chamber (ZECC) is chemically sterilized by spraying 0.5 percent chlorine + 70% alcohol. After that, the mangoes are prepared and washed using water, detergent, and $\text{Ca}(\text{OH})_2$ in accordance with the treatment method. After washing, the mangoes were air-dried and then stored in two different conditions: ZECC and room temperature.

After that, the mango fruit was observed daily for changes until the eighth day of storage.

II.3.2 Main research

The following stage is mango that has received the best treatment during the washing process (1 percent detergent + 0.5 percent $\text{Ca}(\text{OH})_2$), combined with post-harvest technology, specifically packaging techniques utilizing Polypropylene (PP) plastic, and then returned to the sterilized ZECC. Each day, the fruit is analyzed for damage, which is defined as shriveling, softening, dull skin color, the appearance of black spots on the fruit's skin, and the presence of mold at the fruit's base.

II.4 Research design

The design of the research is divided into two stages. The first stage is to determine the optimal treatment for washing mangoes using various washing ingredients, with the following treatments:

A₀ : Control (Without washing)

A₁ : Water-based cleaning

A₂ : 1% detergent + 0.25 % $\text{Ca}(\text{OH})_2$

A₃ : 1% detergent + 0.5% $\text{Ca}(\text{OH})_2$

Following with storage in ZECC and at room temperature, Physical parameters of the fruit skin surface, color, sap, and impurities were observed visually.

The next step is, mango that received the best treatment during the washing process, combined with packaging techniques utilizing Polypropylene (PP) plastic. It is then analyzed every three days using a variety of observation parameters

II.5 Data analysis

The data obtained in the second phase of the study were compiled using a completely randomized design (CRD) with a factorial pattern, namely factor A (type of storage) and factor B (packaged and unpackaged). The research was carried out with three replications.

Data processing used quantitative descriptive method, all parameters were analyzed by analysis of variance (ANOVA) with three replications. The differences for each treatment were further tested using Duncan's test. The software used for data processing is Microsoft Excel 2016 and IBM SPSS Statistics Version 23.

II.6 Observation Parameter

Observation parameters in stage 1 are physical parameters of fruit skin surface, color, sap and dirt. Parameters observed in stage 2 include vitamin C, pH value, water content, total acid, total dissolved solids, weight loss, skin color, hardness test, total microbe, and organoleptic test using 15 panelists.

III. RESULT AND DISCUSSION

III.1 First Phase of Research

The results of the storage of mangoes from the preliminary study showed that mangoes stored at ZECC had better physical quality (visually) than mangoes stored at room temperature. Mangoes stored in ZECC had smoother skin, less noticeable skin discoloration until the 8th day of storage, fewer lenticel spots, and did not grow fungus on the skin surface. The fruit that was stored at room temperature with a rougher skin surface (wrinkled), slightly noticeable skin discoloration, lenticel spots began to appear on the 5th day of storage, as well as fungal growth in some mango samples. These results indicate that storage using the ZECC method is good for extending the shelf life of mangoes compared to storage at room temperature.

III.1.1 Mango Skin Surface

Visual observations of the mango skin's surface revealed that ZECC storage was better compared to room temperature storage. Mango fruits stored in ZECC had smoother skin (not wrinkled) than mango fruits stored at room temperature, which had wrinkled skin surface. The absence of wrinkles in mangoes stored at ZECC is due to the relative humidity (RH) in a good storage room, which is between 80% and 98.04 percent, as opposed to room temperature, which has a relative humidity of 50% to 56.90 percent. This is consistent with Muchtadi (1992), who states that all varieties of mango are susceptible to cold damage in the form of dark spots, uneven ripening, and failure to produce adequate flavor and color, and that a relative humidity of 85-90 percent is required to prevent wilting and softening of various fruits and vegetables (Muchtadi 1992).

The room temperature is higher than the temperature in the ZECC. ZECC has a temperature range of 24-25°C, while the ambient temperature ranges from 26-31°C. Mango fruit stored at room temperature transpired and respired at a faster rate than mango stored in ZECC, causing the mango skin to wrinkle. Because respiration rate is related to the rate of quality deterioration, it can be used to estimate the shelf life of fruit after harvest. As stated by Rizkia (2004) that the slower the rate of respiration, the longer the fruit can be stored in its fresh state; conversely, the faster the rate of respiration, the shorter the shelf life (Rizkia 2004).

III.1.2 Skin color

Mangoes are generally observed visually by observing how clearly the color change from green to yellow appears on the mango skin. Mangoes stored at room temperature and in ZECC without treatment/washing (control), as well as those washed with water and detergent + Ca(OH)₂ exhibited no discernible color changes. On the sixth day of observation, the color changed to a slight yellow hue. This color change occurs because mangoes, as climacteric fruits, accelerate the ripening process during storage. The maturation process that occurs concurrently with the breakdown of chlorophyll, resulting in the appearance of other color pigments such as yellow and red, causing the green color to degrade. This is in line with El-Zeftawi *et al.*, (1988), who stated that the level of chlorophyll content

in green fruit decreases during the storage, other pigments begin to appear, turning the fruit yellow or orange (El-Zeftawi et al. 1988).

III.1.3 Sap and Dirt

For mango fruit washed with water, on day 6 DAW (day after washing), there were still remnants of sap attached to the surface of the mango fruit skin, although they were not particularly noticeable. However, there were a few lenticel spots and a change in color at the fruit's base on day 6 DAW (day after washing) until the 8th day of DAW. While mangoes treated with 1% detergent + 0.25 percent $\text{Ca}(\text{OH})_2$ can visually remove sap, the treatment was more effective at 1% + $\text{Ca}(\text{OH})_2$ 0.5 percent detergent immersion, which resulted in samples of mango fruit being more free of sap and dirt, resulting in a smoother surface with no noticeable changes up to 8 DAW. This is because 1% detergent binds to oil and effectively removes or lifts dirt. Until the eighth day after DAW mango was treated with 1% detergent and 0.5 percent $\text{Ca}(\text{OH})_2$, no lenticel or fungal spots appeared at the base or on the surface of the fruit skin. The surface is smoother and burn-free because the detergent's surfactant active ingredients can remove the oil contained in the sap. Alkaline $\text{Ca}(\text{OH})_2$ solution can neutralize the acid in the sap attached to the golek mango cultivar's skin. This is consistent with Ahmad, S et al (2017)'s finding that the 1% + $\text{Ca}(\text{OH})_2$ 0.5 percent detergent treatment resulted in a lower mean score for reducing lenticel spots at 2 to 14 DAW when compared to the control (Ahmad et al. 2017). In accordance with Taqiyyah (2015), a combination of detergent and $\text{Ca}(\text{OH})_2$ is capable of removing sap and oil from the surface of the Gedong mango skin (Taqiyyah 2015).

III.2 Second Phase of Research

The second stage of this study involved determining the quality and shelf life of mangoes while they were stored. Mangoes that received the best washing treatment (1 percent detergent + 0.5 percent $\text{Ca}(\text{OH})_2$) were then given packaging treatment (using Polypropylene (PP) plastic and without packaging) and then analyzed for quality. Mangoes packaged with Polypropylene (PP) plastic can be stored in ZECC for 21 days, whereas mangoes packaged without Polypropylene plastic have a shelf life of only 18 days.

III.2.1 Weight Loss

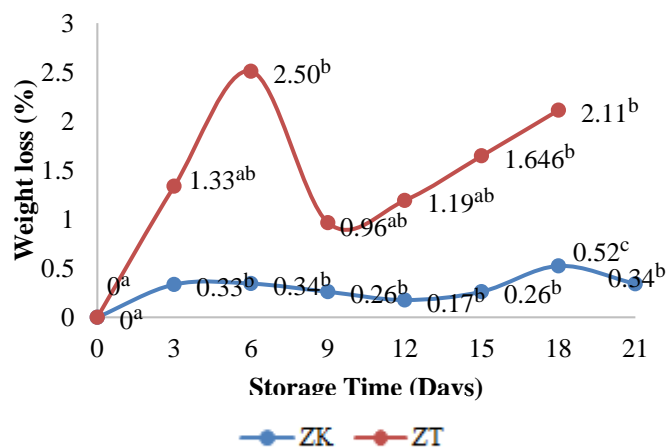


Figure 1. The weight loss of Mangoes During Storage. Values followed by different letters indicate treatment results that are significantly different ($p < 0.05$).

During storage, the mango fruit's weight loss tends to increase. Unpackaged mangoes (ZT) lost approximately twice as much weight as packaged mangoes (ZK). This means that when packaging is used in combination with the ZECC storage technique, mangoes lose less weight. Unpackaged mangoes experienced a greater increase in weight loss due to a high evaporation rate (transpiration), whereas packaged mangoes experienced less water evaporation during storage. Water loss results in withering and shrinking. This is consistent with Winarno (2002), who states that the amount of water in foods determines their freshness, appearance, and durability (Winarno 2002). If some of the water in the food evaporates, weight loss occurs, reducing the food's freshness, appearance, and durability.

In addition to transpiration, weight loss is also influenced by the respiration process of mango fruit. Carbon loss can occur during the respiration process. Carbon compounds contained in the sugar in mangoes will bind and react with oxygen which will produce simple volatile compounds, namely

water vapor and carbon dioxide so that the fruit will lose its weight. So in this case it is known that the respiration process can be suppressed by a combination of packaging and storage in ZECC. This is in accordance with the opinion of Syafutri et al., (2006), which states that the process of fruit respiration can be suppressed by combining packaging and storage at low temperatures(Syafutri, Pratama, and Saputra 2006).

III.2.2 Hardness Level

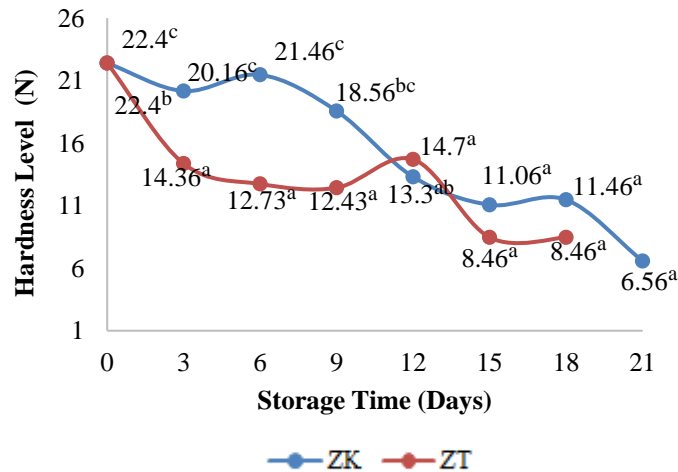


Figure 2. The Hardness Level of Mango Fruit During Storage. Values followed by different letters indicate treatment results that are significantly different ($p < 0.05$).

The ripening process of mangoes during storage results in changes in the level of mango fruit hardness. The ripening process in mangoes occurs concurrently with the conversion or degradation of protopectin to pectin, resulting in a decrease in cell wall rigidity. Mangoes without packaging treatment (ZT) had a greater loss of hardness than mangoes with packaged treatment (ZK). This is due to the fact that unpackaged mangoes have a higher respiration rate and a higher enzyme activity. The more actively these enzymes are, the softer the texture of the fruit. Meanwhile, the rapid rate of respiration causes the fruit tissue to rupture, resulting in the mango becoming soft. The mango with packaging treatment (ZK) can reduce the amount of oxygen received, thereby slowing the respiration process (maintained). This is consistent with Syafutri et al. (2006), who states that the decrease in hardness is also a result of the respiration and transpiration processes (Syafutri et al. 2006). The respiration process results in the breakdown of carbohydrates into simple compounds and tissue rupture, resulting in the mango becoming soft, whereas the transpiration process results in water evaporation, resulting in the mango becoming wilted.

III.2.3 Vitamin C levels

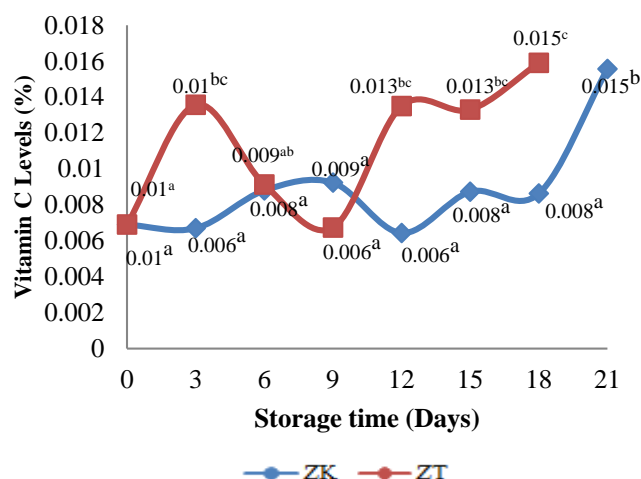


Figure 3. Vitamin C Levels of Mangoes During Storage. Values followed by different letters indicate treatment results that are significantly different ($p < 0.05$).

The levels of vitamin C (ascorbic acid) of mangoes during storage in ZECC tend to vary, both packaged in polypropylene plastic and mangoes without packaging. The significant increase in vitamin C levels of unpackaged mangoes until the end of storage was in line with the faster ripening process of mangoes compared to packaged mangoes. This is in accordance with Pantastico (1986), which states that ripe fruit will increase in acidity, and this increase occurs simultaneously with the climacteric pattern, while vitamin C levels will decrease when the maximum point of increase has been exceeded (withering stage)(Pantastico 1986). The ripening process of unpackaged mangoes is faster because the respiration process is greater than that of packaged mangoes. Mango packaging can regulate/minimize the respiration process of the fruit so that the freshness of the mango can be maintained. This is in accordance with Park et al., (2004), which states that Polypropylene (PP) plastic has high permeability properties which can regulate the rate of atmospheric absorption or respiration rate which can maintain fruit freshness longer(Park, Kim, and Yun 2004). The results of analysis of variance showed that mango without packaging treatment and mango with packaging treatment had a significant effect on vitamin C levels during storage. This is indicated by the value of vitamin C which was initially low and then increased until the end of storage. The increase or decrease in vitamin C is because the vitamin is unstable, easily oxidized when exposed to air (oxygen) and this process can be accelerated by storage temperature. This is in accordance with Tannenbaum (1976), stating that the reduction of O_2 will inhibit the degradation of ascorbate into dehydroascorbic acid and H_2O_2 (Tannenbaum 1976). The resulting H_2O_2 will cause autoxidation so that it will increase the damage of vitamin C.

III.2.4 Total Acid

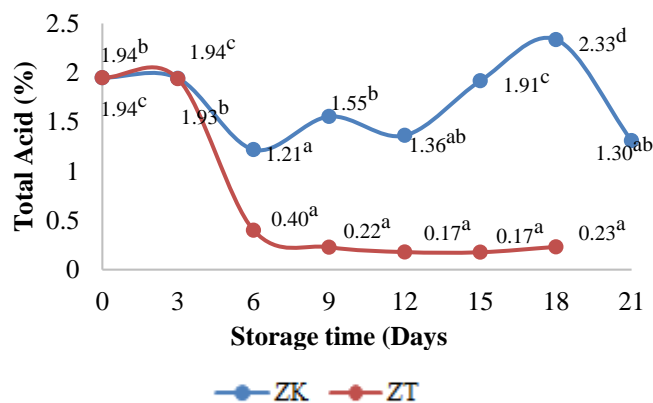


Figure 4. Total Acid Level of Mango Fruit During Storage. Values followed by different letters indicate treatment results that are significantly different ($p < 0.05$).

The total acid value of mango in ZECC storage, both packaged and unpackaged, tends to decrease, though the trend is variable. The percentage of total acid in the fruit decreases as the fruit is stored. The decrease in the percentage of total acid is due to the respiration process's use of organic acids, as well as the use of organic acids by microbes in energy-consuming activities. This energy is

obtained through the breakdown of the nutrients found in food. Organic acids are converted to sugars during the respiration process. Amalya et al. (2017) found in their research that the fruit's decreased organic acid value indicated that the fruit's ripening metabolism was functioning normally (Khairi, Falah, and Pamungkas 2017).

Total acid in mangoes that were not packaged (ZK) degraded more rapidly than in packaged mangoes (ZK). This is due to the respiration process of unpackaged mangoes. Merynda et al. (2006) state that when mangoes are not packaged, the respiration process cannot be minimized due to the abundant O₂ in the environment (Syafutri et al. 2006).

III.2.5 Total Dissolved Solids (TDS)

Mangoes' total dissolved solids (packaged and unpackaged) exhibit a fluctuating graph. Unpackaged mangoes (ZT) underwent a maximum ripening process, as indicated by the percentage of TDS value increasing significantly at first and then gradually decreasing until the end of storage. The increase in TDS is a result of starch hydrolysis during ripening process. While the decrease in TDS occurs as a result of the abundant O₂ available in the environment, it may be which contributes to the respiration process. Thus, glucose as the result of starch hydrolysis then was consumed during the respiration process, resulting in a rapid decrease in the sugar content of the fruit. Pantastico (1993) confirms this by stating that during ripening, starch is hydrolyzed into simple compounds that serve as a source of energy during the respiration process (Pantastico 1986). At this point, the sucrose has been converted back to glucose and fructose. The decrease in total sugar content of unpackaged mangoes occurred as the mango fruit began to ripen, at which point the starch content began to decrease and the activity of the invertase enzyme decreased, resulting in a decrease in sugar content. The mango with packaging (ZK) has the ability to maintain the fruit's ripening process, as indicated by the predominant fluctuating TDS value. This demonstrates that by combining packaging and storage in ZECC, the rate of decrease in the percentage of TPT in mangoes can be slowed.

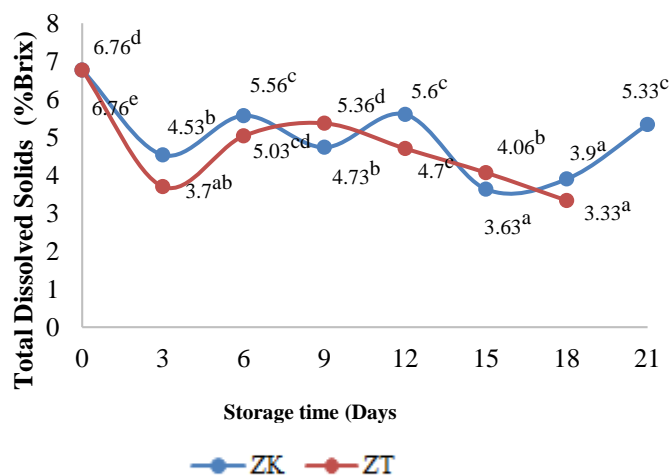


Figure 5. Total Dissolved Solids of Mango Fruit During Storage. Values followed by different letters indicate treatment results that are significantly different ($p < 0.05$).

This variable total dissolved solids value is also a result of the fruit's non-uniform maturity level. Non-uniform fruit ripeness causes abnormal respiratory activity so that the breakdown process of simple sugars varies. In general, changes in total dissolved solids content increased at the maximum point of storage and then decreased until the fruit began to rot on the final day of storage. This is consistent with Biale and Young's (1971) observation that the general trend is for a rapid increase in sugar content followed by a decline; in climacteric fruit, this condition becomes a marker (Biale and Young 1971).

III.2.6 Degree of Acidity (pH)

According to the graph, mango fruit are acidic, with a pH value ranging between 2 and 6 during storage. The ripening of mangoes alters the pH value of the fruit. Without packaging treatment (ZT), mangoes matured rapidly (maximum), increasing the pH value. It is not the case with packaged mangoes (ZK), as their ripening process is slowed, resulting in a stable pH value throughout storage. As the mango ripens, the acid content decreases while the simple sugars increase, as indicated by the decrease in total acid content. The pH value is directly proportional to vitamin C levels and inversely

proportional to total acidity, as shown in the graph. This is consistent with Amalya et al., (2017), who state that changes in pH indicate changes in the composition of the fruit's cell fluid as it matures; the pH value that tends to be high is related to relatively high ascorbic acid (vitamin C) levels during storage; this change indicates that the fruit's metabolism affects the pH value (Khairi et al. 2017).

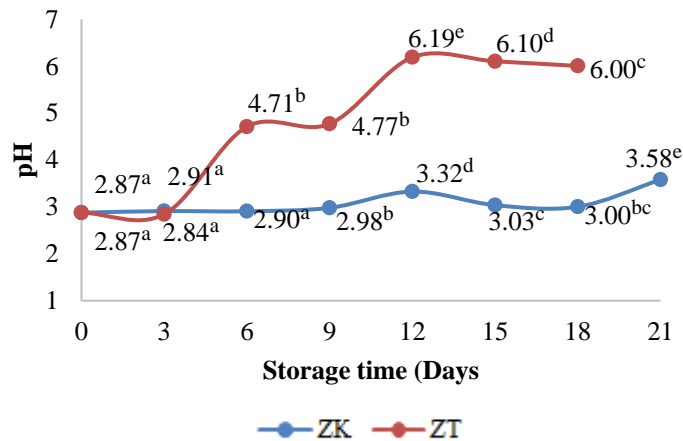


Figure 6. pH Value (Degree of Acidity) Mango Fruit During Storage. Values followed by different letters indicate treatment results that are significantly different ($p < 0.05$).

III.2.7 Water content

The water content of mangoes stored in the ZECC method varied slightly during storage. When compared to unpackaged mangoes, packaged mangoes (ZK) are able to maintain changes in water content during storage. This is because PP packaged mangoes have a high permeability, which minimizes changes in water content during storage. This is consistent with Schwartz (2009), who states that because of the packaging, ambient air cannot easily enter the material, thereby inhibiting the process of water exchange during storage (Schwartz 2009).

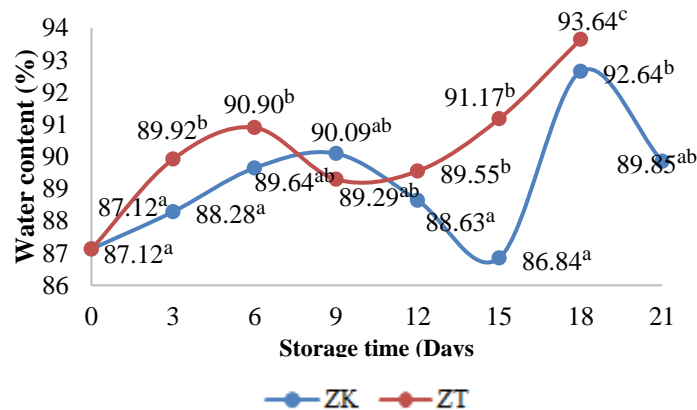


Figure 7. Water Content of Mangoes During Storage. Values followed by different letters indicate treatment results that are significantly different ($p < 0.05$).

Due to the high humidity in ZECC storage, which reached 80-90 percent, mango fruit experienced an increase and decrease in water content during storage. Due to the high humidity level in the ZECC room, moisture absorption from the environment into the stored mango is possible. The longer the storage time, the higher the water content will remain. According to Herawati (2008), a significant factor influencing the decline in the quality of food products is changes in the product's water content, which can be influenced by the room's temperature and humidity during storage (Herawati 2008). This opinion is backed up by Retnani et al., (2009), who state that the high humidity of the storage room can result in the absorption of water vapor from the air into the foodstuffs, resulting in an increase in water content (Retnani et al. 2009).

Additionally, the increase in water content during storage is a result of the mangoes' respiration process. During storage, the fruit undergoes a ripening process that includes the conversion of starch to simple sugars ($C_6H_{12}O_6$). These simple sugars then interact with the oxygen (O_2) in the chamber, increasing the rate of water (H_2O) formation in the fruit. This is consistent with Nurhayati S (2004), who states that one of the causes of changes in the water content of fruit is the respiration process, during which water is formed as a result of sugar reorganization into simpler compounds.

III.2.8 Color

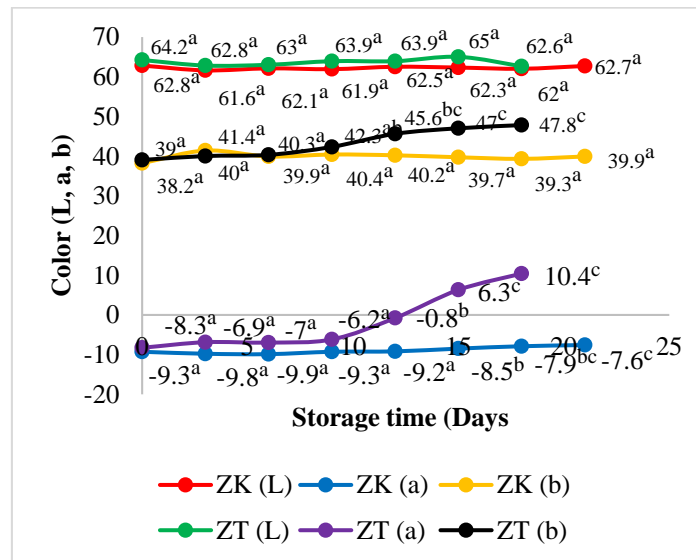


Figure 8. Analysis of Mango Skin Color During Storage. Values followed by different letters indicate treatment results that are significantly different ($p < 0.05$).

The L^* value indicates the brightness level of the mango fruit, which indicates the reflected light that produces achromatic colors of white, gray and black, ie from a value of 0 (black) – 100 (white). The L^* value of unpackaged and packaged mangoes had a very small decrease in lightness value during storage. The range of changes in the L^* value from 65-62 indicates a slight decrease in brightness level during storage. The longer the fruit is stored, the lower the brightness level of the mango. According to Ahmad et al., (2014), that the brightness level of the color will decrease which will be directly proportional to the longer the shelf life, the fruit will lead to spoilage in the end(Ahmad, Darmawati, and Refilia 2014). The decreasing brightness level of the mango skin color is caused by changes in the chlorophyll content of the fruit. This is in accordance with the statement of Syafutri et al., (2006), which states that the reduced level of color brightness in fruit during storage is caused by reduced chlorophyll content in fruit skins and the appearance of carotenoids(Syafutri et al. 2006).

The a^* value is a value that shows the gradation of green to red. A mixed red-green chromatic color with a value of $+a^*$ (positive) from 0 to +80 for red and a value of $-a^*$ (negative) from 0 to -80 for green. The a^* value of mango tends to increase during the storage process. Mangoes tend to be green, indicated by an a^* value below 0, but the longer the storage time, the color of the fruit moves to red. The significant increase in a^* value was caused by the high respiration rate of unpackaged mangoes so that the degradation of chlorophyll was also rapid which had the effect of accelerating the synthesis of pigment (color change) of the fruit. This is in accordance with the opinion of Masfufatun et al. (2015), which states that a high respiration rate will also cause chlorophyll degradation and pigment synthesis to be fast, consequently accelerating color changes(Masfufatun, Kumala, and Rahayuningsih 2009).

The b^* value indicates the color gradation to yellow. A mixed blue-yellow chromatic color with a $+b^*$ (positive) value from 0 to +70 for yellow and a $-b^*$ (negative) value from 0 to -70 for blue. Based on the figure 8, it shows that unpackaged mangoes have a slowly increasing b^* value during storage compared to packaged mangoes whose b^* values tend to be stable until the end of storage. The results of the measurement of the b^* value show that the longer the storage, the yellow color of the mango will be clearer. The increasing b^* value in unpackaged mangoes indicates that the fruit is getting more mature than the packaged mangoes during storage. This is in accordance with the statement of Kusumiyati et al., (2018), which states that the longer the storage, the yellow color of the mango is more clearly marked by the higher the mean b^* value. The higher the b^* value in the mango can be indicated the higher the ripeness level of the fruit(Kusumiyati et al. 2018).

III.2.9 Organoleptic test

III.2.9.1 Color

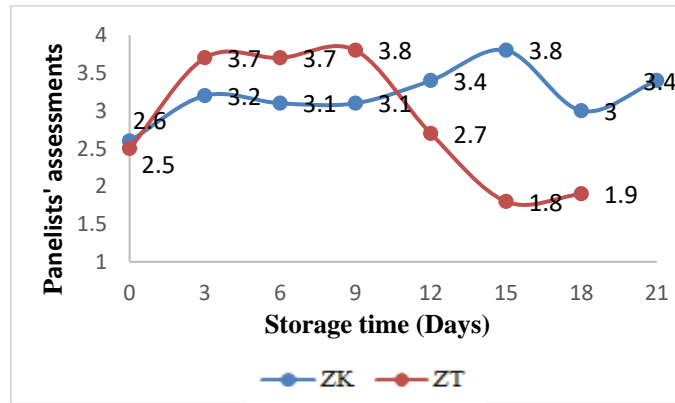


Figure 9. Results of Organoleptic Testing on Mango Color in ZECC Storage

The changes in panelists' assessments of organoleptic color parameters in mangoes were due to the nature of mangoes undergoing post-harvest ripening (after harvesting), specifically that the color will change during the storage process due to chlorophyll degradation into other pigments. The panelists' assessment of mangoes with packaging treatment (ZK) tended to remain stable until the end of storage, with an average value of 3 (slightly similar), whereas mangoes without packaging (ZT) maintained an average value of 4 (similar) until the ninth day of storage, when it decreased until the end of storage. This demonstrates that mangoes treated with packaging can help preserve or delay the color change of mangoes stored in ZECC. Packaging treatment on mangoes can slow the respiration process, resulting in a slower color change and maturation and aging process. This is consistent with Kamilia (2017), who states that a faster respiration rate can accelerate the senescence process, which results in a more rapid color change.

III.2.9.2 Aroma

The panelists' evaluations of the mango aroma parameters revealed a range of results but a consistent pattern of increasing and then decreasing until the end of storage. In terms of fruit aroma, panelists prefer the unpackaged aroma of mango fruit.

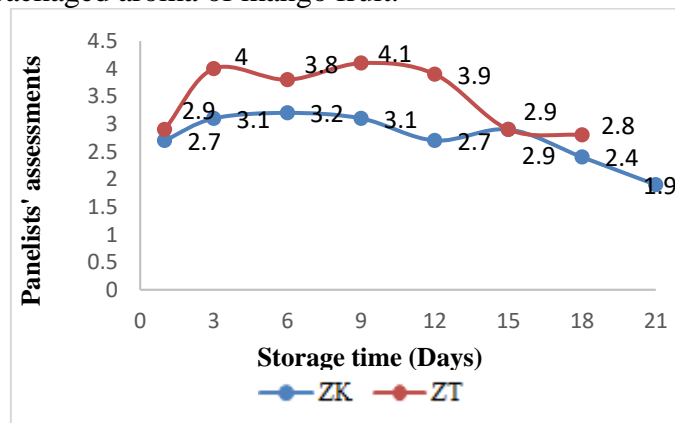
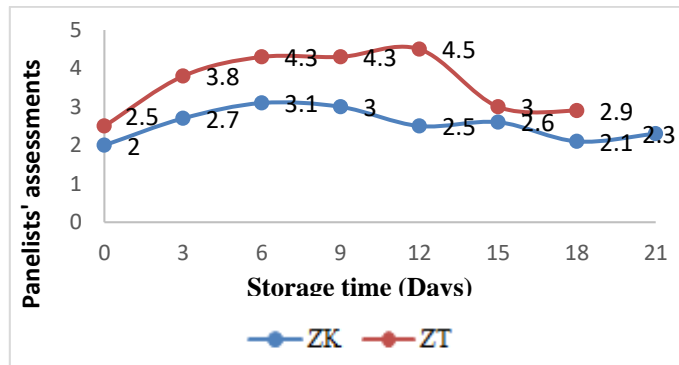


Figure 10. Results of Organoleptic Testing on Mango Aroma in ZECC Storage

The high acceptance of unpackaged mango aroma (ZT) is a result of the increasing ripening process (perfect ripening), which results in an increase in the production of volatile components. While the packaged mango (ZK) took longer to decompose, the panelists generally disliked it due to the incomplete ripening process, which resulted in a low flavor. This is consistent with Muchtadi (1992), who stated that ripening typically results in an increase in the content of simple sugars, which imparts a sweet flavor, as well as an increase in the production of volatile substances, which imparts a distinctive fruit flavor.

III.2.9.3 Taste



Gambar 11. Results of Organoleptic Testing on Mango Taste in ZECC Storage

The results of organoleptic tests on mangoes stored at ZECC showed that the panelists' assessment of fruit taste increased and then decreased until the end of storage. The range of values between 3-5 (based on the graph) shows that the panelists' assessment of unpackaged mangoes (ZT) is dominantly preferable to mangoes with packaged treatment (ZK) with a value of 2-3. The high rating for unpackaged mangoes is because the mangoes undergo an even ripening process during storage, resulting in a distinctive taste and good color which are preferred by panelists (Ali 2017). The sweet taste is due to the change in the starch content of the fruit to sugar during storage. This is in accordance with the statement of Mulyati (2012), that changes during the ripening process are changes in starch and fat reserve materials into various sugars (Mulyati 2012). The mango with packaging (ZK) undergoes a slow ripening process due to its low respiration rate in the presence of packaging, but it takes longer to decay or damage in ZECC storage.

IV.2.9.4 Texture

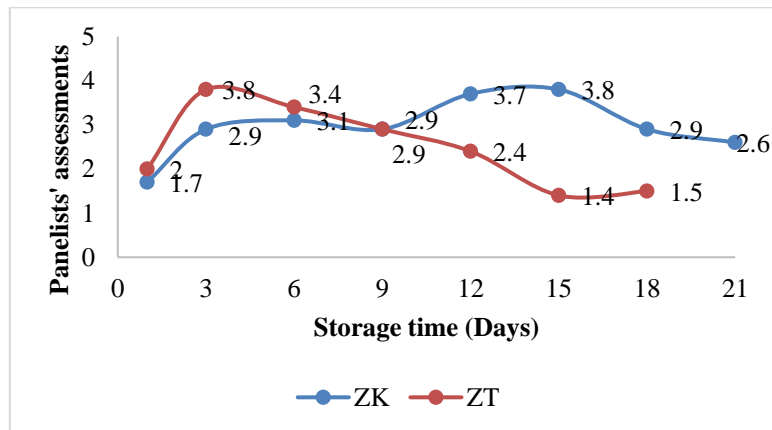


Figure 12. Results of Organoleptic Testing on Mango Texture in ZECC Storage

Panelists determined that mango with packaged treatment (ZK) (mean value 3-4) was preferable in terms of texture because the level of hardness did not decrease significantly (soft), as opposed to mango without packaged treatment (ZT) (mean value 2-3). The texture began as hard, which the panelists disliked, then softened slightly, which the panelists liked, and finally became extremely soft due to damage/rotting, which the panelists disliked. When the qualitative (organoleptic test of texture parameters) analysis of mango fruit is combined with quantitative analysis (with a penetrometer), it is discovered that the level of hardness (the process of hardness decreasing) is directly proportional during storage.

Mangoes' softening texture is caused by the ripening process that occurs during storage. Maturation occurs concurrently with the conversion or degradation of insoluble protopectin to soluble pectin. The reshuffle occurs as a result of the action of enzymes such as pectin methyl esterase, which softens the fruit. Protopectin levels in the fruit decrease as the fruit ripens, while pectin levels increase. This is in accordance with Afrazak et al., (2014), that as fruit ripens and stores, some of the water-insoluble protopectin converts to water-soluble pectin, reducing the cohesion of the cell walls that connect cells, resulting in a decrease in texture or fruit hardness and the fruit becoming soft (Johansyah and Kusdiantini 2014). Additionally, the rate of respiration has an effect on the degree of hardness or texture. Unpackaged mangoes with a high respiration rate cause the fruit's

tissue to rupture and enzyme activity to accelerate, resulting in a softer fruit texture. The mango with packaging treatment (ZK) can reduce the amount of oxygen received, thereby slowing the respiration process (maintained).

III.2.10 Microbial Analysis (Yeast Mold Count)

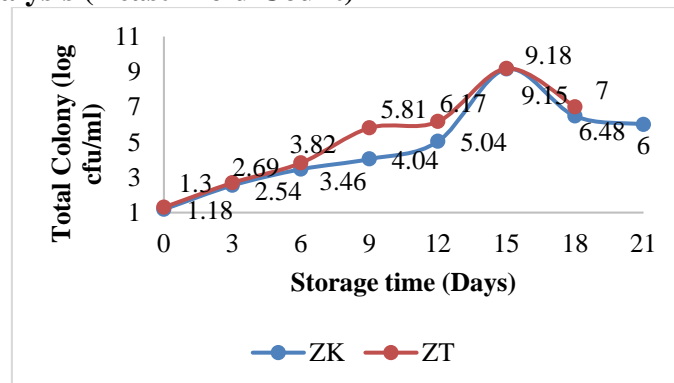


Figure 13. Mold and Yeast cell count on Mangoes During Storage in ZECC

According to the graph, the results of microbial analysis (mold and yeast counts) on mango fruit storage in ZECC indicated that yeast mold growth continued to increase and then decreased gradually until the end of storage. Microbial growth (mold and yeast) that began low/small and then increased to a maximum growth peak on the 15th day generally indicated that the mangoes' quality deteriorated during storage and gradually entered the senescence phase. This also demonstrates that mangoes with a relatively high sugar content and a low pH provide an ideal environment for molds and yeasts to grow to their maximum growth capacity during storage. This is consistent with Seema R (2015) statement that fruit with a high sugar content and a low/acidic pH (pH range between 3-8) promotes the growth of fungi (mold/yeast) after the fruit is harvested (Rawat 2015).

Mango without packaging (ZT) exhibited a greater increase in the growth of the dominant mold/yeast than mango with packaging (ZK). This demonstrates that by combining calcium hydroxide washing with packaging on mangoes stored in ZECC, the rate of microbial growth can be slowed or suppressed, thereby extending the fruit's life phase. Certain microbes require oxygen to grow, which can be suppressed through packaging. This is consistent with the opinion of Ira M et al. (2017), who state that treating fruit with packaging technology can suppress the air activity required by microbes, thereby slowing the growth rate of pathogenic microbes (Mulyawanti, Syaefullah, and Amiarsi 2018).

IV. Conclusions

It can be concluded that analysis of the quality of golek mango (*Mangifera indica* L.) physically, chemically, microbiologically, and sensory in the Zero Energy Cool Chamber (ZECC) storage technique shows that ZECC can maintain optimal fruit quality through a washing treatment process (chemically) in combination with packaging. In addition, the Zero Energy Cool Chamber (ZECC) storage method with a combination of washing and packaging treatments is effective in maintaining the quality of mangoes up to 21 days of storage.

V. Acknowledgment

This research was funded by the Directorate General of Research and Development, Ministry of Research, Technology and Higher Education, Republic of Indonesia, through LPPM Unhas : Penelitian Terapan 2020 Number 7 /E1/KP.PTNBH/2021.

References

- Ahmad, Sutopo, Roedhy Poerwanto, and Suryo Wiyono. 2017. "Keefektifan Bahan Pencuci Dan Pencegah Penyakit Terhadap Kualitas Buah Mangga CV. Gedong Gincu Dan Arumanis (The Effectiveness of Washing Materials and Disease Protecting Agent on the Quality of Mango Fruit Cv. Gedong Gincu and Arumanis)." *Jurnal Hortikultura* 27(2):253–60.
- Ahmad, Usman, Emmy Darmawati, and Nur Rahma Refilia. 2014. "Kajian Metode Pelilinan Terhadap Umur Simpan Buah Manggis (*Garcinia mangostana*) Semi-Cutting Dalam Penyimpanan Dingin." *Jurnal Ilmu Pertanian Indonesia* 19(2):104–10.
- Ali, Kamilia Nur Yaumil. 2017. "Mutu Buah Mangga (*Mangifera indica* L.) Dan Tomat (*Lycopersicon esculentum* Mill.) Yang Disimpan Pada ZECC (Zero Energy Cool Chamber)." Universitas Hasanuddin.
- Biale, J. B. and R. Young. 1971. *The Avocado Pear. Dalam Hulme, A.C. The Biochemistry of Fruit and Their Produce*. London: Academic Press.
- Dirpan, A. 2019. "The Quality of Tomato (*Lycopersicon esculentum* Mill.) Stored on ZECC (Zero Energy Cool Chamber)." P. 12012 in *IOP Conference Series: Earth and Environmental Science*. Vol. 270. IOP Publishing.
- Dirpan, Andi. 2008. *ZECC (Zero Energy Cool Chamber) Penyimpanan Dingin Yang Murah Dan Ramah Lingkungan Untuk Memperpanjang Masa Simpan Buah Dan Sayur Setelah Panen*. Makassar: Universitas Hasanuddin.
- Dirpan, Andi, Muhammad Tahir Sapsal, Abdul Kadir Muhammad, Mulyati M. Tahir, and Rahimuddin. 2017. "Evaluation of Temperature and Relative Humidity on Two Types of Zero Energy Cool Chamber (ZECC) in South Sulawesi, Indonesia." *IOP Conference Series: Earth and Environmental Science* 101:012028.
- El-Zeftawi, B. M., L. Brohier, L. Dooley, F. H. Goubran, R. Holmes, and B. Scott. 1988. "Some Maturity Indices for Tamarillo and Pepino Fruits." *Journal of Horticultural Science* 63(1):163–69.
- Herawati, Heny. 2008. "Penentuan Umur Simpan Pada Produk Pangan." *Jurnal Litbang Pertanian* 27(4):124–30.
- Islam, M. P. and T. Morimoto. 2015. "ScienceDirect Evaluation of a New Heat Transfer and Evaporative Design for a Zero Energy Storage Structure." *Solar Energy* 118:469–84.
- Islam, M. P., T. Morimoto, and K. Hatou. 2013. "Dynamic Optimization of inside Temperature of Zero Energy Cool Chamber for Storing Fruits and Vegetables Using Neural Networks and Genetic Algorithms." *Computers and Electronics in Agriculture* 95:98–107.
- Johansyah, Afrazak and Endang Kusdiantini. 2014. "Pengaruh Plastik Pengemas Low Density Polyethylene (LDPE), High Density Polyethylene (HDPE) Dan Polipropilen (PP) Terhadap Penundaan Kematangan Buah Tomat (*Lycopersicon esculentum* Mill)." *Anatomi Fisiologi* 22(1):46–57.
- Khairi, Amalya Nurul, Affan Fajar Falah, and Agung Putra Pamungkas. 2017. "Analisis Mutu Pascapanen Melon (*Cucumis melo* L.) Kultivar Glamour Sakata Selama Penyimpanan." *CHEMICA: Jurnal Teknik Kimia* 4(2):47–52.
- Kusumiyati, Kusumiyati, Farida Farida, Wawan Sutari, and Syariful Mubarak. 2018. "Kualitas Buah Mangga Selama Penyimpanan Pada Keranjang Anyaman Bambu Dengan Identifikasi Ruang Warna L*, A* Dan B." *Kultivasi* 17(2):628–32.
- Masfufatun, Widaningsih, N. Kumala, and T. Rahayuningsih. 2009. "Pengaruh Suhu Dan Waktu Penyimpanan Terhadap Vitamin c Dalam Jambu Biji (*Psidium guajava*)." *Universitas Wijaya Kusuma, Surabaya*.
- Muchtadi, Dedy. 1992. *Fisiologi Pasca Panen Sayuran Dan Buah-Buahan: Petunjuk Laboratorium*. Institut Pertanian Bogor.
- Mulyati. 2012. *Sayur-Sayuran, Buah-Buahan Penanganan Dan Pengolahannya*. Makassar: CV.

Indo media.

- Mulyawanti, Ira, Enrico Syaefullah, and Dwi Amiarsi. 2018. "Teknologi Pengemasan Atmosfir Termodifikasi (Modified Atmosphere Packaging/Map) Dan Vakum Pada Buah Durian."
- Pantastico, E. B. 1986. *Fisiologi Pascapanen, Penanganan Dan Pemanfaatan Buah-Buahan Dan Sayur-Sayuran Tropika Dan Subtropika (Terjemahan Kamariyani 1997)*. Yogyakarta: Gajah Mada University Press.
- Park, T., Y. A. Kim, and J. Yun. 2004. "The Need for Collaboration in the Supply Chain For Successful Direct Shipments." in *Proceedings of the Thirty-Third Annual Meeting of the Western Decision Sciences Institute*.
- Rawat, Seema. 2015. "Food Spoilage: Microorganisms and Their Prevention." *Asian Journal of Plant Science and Research* 5(4):47–56.
- Retnani, Y., W. Widiarti, I. Amiroh, L. Herawati, and K. B. Satoto. 2009. "Daya Simpan Dan Palatabilitas Wafer Ransum Komplit Pucuk Dan Ampas Tebu Untuk Sapi Pedet." *Media Peternakan* 32(2):130–36.
- Rizkia. 2004. "Kajian Laju Respirasi Dan Perubahan Mutu Buah Mangga Gedong Gincu Selama Penyimpanan Dan Pematangan Buatan." Institut Pertanian Bogor.
- Schwartz, Naomi. 2009. "Pengaruh Jenis Bahan Pengemas Terhadap Kualitas Cabe Merah Segar Selama Penyimpanan Dingin." Universitas Sumatra Utara.
- Syafutri, Merynda I., F. Pratama, and D. Saputra. 2006. "Sifat Fisik Dan Kimia Buah Mangga (*Mangifera Indica L.*) Selama Penyimpanan Dengan Berbagai Metode Pengemasan." *Jurnal Teknologi Dan Industri Pangan* 17(1):1–11.
- Tannenbaum. 1976. *Vitamins and Mineral*. New York (US: MerceL Dekker.
- Taqqiyah, Affifah. 2015. "Pengaruh Penambahan Fungisida Pada Bahan Pencuci Serta Suhu Penyimpanan Terhadap Peningkatan Kualitas Mangga. (*Mangifera Indica L.*)"
- Winarno. 2002. *Fisiologi Lepas Panen Produk Hortikultura*. Bogor: M-Brio Press.

Paper accepted for publication

Acceptance letter

External

Inbox



ram kishan <rkishan05@rediffmail.com> Sun, Oct 24, 2021, 7:55 PM

to me

Dear Author,

I am pleased to inform you that on recommendations of referees your research article entitled " Extending of Mango (*Mangifera Indica* L.) Shelf Life with Combination of Zero Energy Cool Chamber (ZECC)Storage Technology, Washing and Packaging (ref.no.8072)" coauthored with Muhammad Tahir Sapsal, Mulyati M Tahir, Muspirah Djalal and Ashabul Firdaus has been accepted for publication in International Journal of Agricultural and Statistical Sciences and will be published in Vol.17,1, 2021.

Thanking you

Dr.Ram Kishan
Chief-Editor,IJASS

Final proofreading before publication

Proof 8072

External

Inbox



ram kishan <rkishan05@rediffmail.com> Fri, Nov 5, 2021, 2:20 PM

to me

Dr.Ram Kishan
Chief-Editor,IJASS

Attachments area



Andi Dirpan <dirpan@unhas.ac.id> Nov 5, 2021, 2:26 PM

to ram

Dear Dr. Ram,

Thank you for your email. If you don't mind, can you send us the word file? Therefore, we can revise directly on it.

Best regard

Andi



Andi Dirpan <dirpan@unhas.ac.id> Nov 16, 2021, 5:43 PM

to ram

Dear Dr. Ram

Please find attached the file of our manuscript. We have revised the manuscript based on your suggestion. We used the track changes in MS word to show easily our revision.

Please note that the point **Microbial Analysis (Yeast Mold Count)** must be 3.2.10. We also put a comment about this in the file. If you don't mind please send back to us the galley proof before publishing our paper.

thank you

Best regards

Andi



ram kishan <rkishan05@rediffmail.com> Wed, Nov 17, 2021, 9:37 PM

to me

Dr.Ram Kishan
Chief-Editor,IJASS

From: Andi Dirpan <dirpan@unhas.ac.id>
Sent: Tue, 16 Nov 2021 15:13:49
To: ram kishan <rkishan05@rediffmail.com>
Subject: Re: Proof 8072

Dear Dr. Ram

Please find attached the file of our manuscript. We have revised the manuscript based on your suggestion. We used the track changes in MS word to show easily our revision.

Please note that the point **Microbial Analysis (Yeast Mold Count)** must be 3.2.10. We also put a comment about this in the file. If you don't mind please send back to us the galley proof before publishing our paper.

thank you

Best regards

Andi

Extending of Mango (*Mangifera Indica L.*) Shelf Life with Combination of Zero Energy Cool Chamber (ZECC) Storage Technology, Washing and Packaging¹⁾

Andi Dirpan*, Muhammad Tahir Sapsal, Mulyati M Tahir, Muspirah Djalal and Ashabul Firdaus

*dirpan@unhas.ac.id

Department of Agricultural Technology, Hasanuddin University Makassar 90245, Indonesia

ABSTRACT

Mangoes suffer up to a 20%-50% shrinkage, loss, and quality damage as a result of improper harvest and post-harvest handling, as well as poor storage conditions. The presence of a post-harvest technology system of Zero Energy Cool Chamber (ZECC) storage combined with pre-handling treatment (washing and packaging) is one method of minimizing damage and extending the shelf life of mangoes. This study aimed to determine the mango golek's quality and shelf life by using ZECC in combination with washing and packaging. This study used a completely randomized design (CRD) with factorial patterns, specifically factor A (storage type) and factor B (packaging and without packaging). The study's observation parameters were divided into two stages, with stage 1 consisting of physical parameters and stage 2 consisting of chemical, microbiological, and sensory parameters. According to preliminary research, the best treatment is washing with 1% detergent + 0.5 percent $\text{Ca}(\text{OH})_2$, which results in a smoother skin surface, less noticeable discoloration, and a cleaner surface free of sap and dirt. Physical, chemical, microbiological, and sensory analysis of mango golek (*Mangifera indica L.*) demonstrates that the ZECC storage technique can maintain fruit quality optimally in combination with washing (chemical) and packaging treatment processes, and it can effectively protect the mango golek's quality for up to 21 days.

Keywords: Fruit Quality, Postharvest Technology

I. INTRODUCTION

Indonesia possesses immense natural resource potential, particularly in horticultural crops like mango. According to the Indonesian Central Statistics Agency, mango production reached 2,431,329 tons per year in 2014 and 2,178,833 tons per year in 2015, a decrease of 10.39 percent. Mango productivity continues to be harmed by improper harvesting and postharvest handling, which degrades the quality of the mangoes. Additionally, storage conditions are insufficient during agricultural product distribution and marketing, resulting in fruit depreciation. According to research conducted in developing countries, improper harvesting and post-harvest handling can result in fruit yield losses ranging from 20% to 50% (Dirpan et al. 2017)

Cold storage is one technique for postharvest handling. However, rural areas, which are typically agricultural centers, have severe shortages of cold storage, such as refrigerators. Additionally, the high operational costs associated with cold storage present a significant barrier to farmers employing post-harvest handlers. Additionally, it produces freon, an environmentally hazardous chemical (Dirpan et al. 2017). In light of the aforementioned issues, we require an energy-free (zero energy) cold storage system that is also affordable (low cost) and environmentally friendly (eco friendly), one of which is the Zero Energy Cool Chamber (ZECC) (Islam and Morimoto 2015).

The Zero Energy Cool Chamber (ZECC) is a cost-effective and environmentally friendly method of storing fruits and vegetables following harvest. Due to the fact that ZECC does not require electricity to operate, it is frequently referred to as an environmentally friendly fruit and vegetable storage system (Dirpan 2019; Islam, Morimoto, and Hatou 2013). Additionally, this storage system is cost effective due to the fact that it makes use of readily available materials such as bricks, sand, plastic roofs, and water (Dirpan et al. 2017; Islam et al. 2013)

Recent years have seen an increase in research on fruit and vegetable storage methods utilizing ZECC, as demonstrated by Ali et al. (2017) and Dirpan et al. (2018) studies examining the

quality of mangoes and tomatoes stored in ZECC (Ali 2017; Dirpan 2008). However, because fungi grew around the mangoes in the aforementioned studies, ZECC was used in conjunction with pre-handling treatments such as washing and packaging to minimize the possibility of mold and yeast growth and to extend the shelf life of the golek mango. As a result, the purpose of this research were: to determine the physical, chemical, microbiological, and sensory characteristics of mango golek stored in a ZECC (Zero Energy Cool Chamber) in combination with washing and packaging processes and to determine the shelf life of mangoes stored in a ZECC (Zero Energy Cool Chamber) in combination with washing and packaging processes.

II. Materials and Methods

II.1 Date and Location of Research

This research was conducted from July to November 2019 at the Food Processing Laboratory and the Chemical Laboratory of Food Quality Analysis and Supervision of the Food Science and Technology Study Program, Department of Agricultural Technology, Faculty of Agriculture, Hasanuddin University, as well as at the Research Activity Center (PKP) building and Lecturer Housing Unhas Tamanlarea, Makassar.

II.2 Instruments and materials

The tools used in this research include a zero energy cool chamber (ZECC), polypropylene plastic packaging, fruit racks, temperature and relative humidity sensors, hoses, scales, analytical scales, and moisture, analyzer, colorimeter, penetrometer, digital hand refractometer, pH meter, stirring rod, beaker, erlenmeyer flask, volumetric flask, dropper pipette, volume pipette, petri dish, autoclave, bulb, micropipet, test tube, tube rack, laminar air flow (LAF), plates, spoons, knives, rags, blenders.

Materials used in this study were 77 golek mango (main ingredient) with a maturity index of 2 (light green), aquadest, detergent, chlorine, calcium hydroxide ($\text{Ca}(\text{OH})_2$), sodium hydroxide (NaOH), iodine, indicator phenolphthalein, alcohol, buffer pH 7, mineral water, starch indicator (starch), potato dextrose agar (PDA) medium, inhibitor (chloramphenicol), cotton, and labels.

II.3 Research procedure

The research process is as follows:

II.3.1 Preliminary research

Mangoes are sorted, and then those that are not rotten or injured are selected for this research. The mango is then graded according to its maturity level. Following that, the Zero Energy Cool Chamber (ZECC) is chemically sterilized by spraying 0.5 percent chlorine + 70% alcohol. After that, the mangoes are prepared and washed using water, detergent, and $\text{Ca}(\text{OH})_2$ in accordance with the treatment method. After washing, the mangoes were air-dried and then stored in two different conditions: ZECC and room temperature.

After that, the mango fruit was observed daily for changes until the eighth day of storage.

II.3.2 Main research

The following stage is mango that has received the best treatment during the washing process (1 percent detergent + 0.5 percent $\text{Ca}(\text{OH})_2$), combined with post-harvest technology, specifically packaging techniques utilizing Polypropylene (PP) plastic, and then returned to the sterilized ZECC. Each day, the fruit is analyzed for damage, which is defined as shriveling, softening, dull skin color, the appearance of black spots on the fruit's skin, and the presence of mold at the fruit's base.

II.4 Research design

The design of the research is divided into two stages. The first stage is to determine the optimal treatment for washing mangoes using various washing ingredients, with the following treatments:

A₀ : Control (Without washing)

A₁ : Water-based cleaning

A₂ : 1% detergent + 0.25 % Ca(OH)₂

A₃ : 1% detergent +0.5%Ca(OH)₂

Following with storage in ZECC and at room temperature, Physical parameters of the fruit skin surface, color, sap, and impurities were observed visually.

The next step is, mango that received the best treatment during the washing process, combined with packaging techniques utilizing Polypropylene (PP) plastic. It is then analyzed every three days using a variety of observation parameters

II.5 Data analysis

The data obtained in the second phase of the study were compiled using a completely randomized design (CRD) with a factorial pattern, namely factor A (type of storage) and factor B (packaged and unpackaged). The research was carried out with three replications.

Data processing used quantitative descriptive method, all parameters were analyzed by analysis of variance (ANOVA) with three replications. The differences for each treatment were further tested using Duncan's test. The software used for data processing is Microsoft Excel 2016 and IBM SPSS Statistics Version 23.

II.6 Observation Parameter

Observation parameters in stage 1 are physical parameters of fruit skin surface, color, sap and dirt. Parameters observed in stage 2 include vitamin C, pH value, water content, total acid, total dissolved solids, weight loss, skin color, hardness test, total microbe, and organoleptic test using 15 panelists.

III. RESULT AND DISCUSSION

III.1 First Phase of Research

The results of the storage of mangoes from the preliminary study showed that mangoes stored at ZECC had better physical quality (visually) than mangoes stored at room temperature. Mangoes stored in ZECC had smoother skin, less noticeable skin discoloration until the 8th day of storage, fewer lenticel spots, and did not grow fungus on the skin surface. The fruit that was stored at room temperature with a rougher skin surface (wrinkled), slightly noticeable skin discoloration, lenticel spots began to appear on the 5th day of storage, as well as fungal growth in some mango samples. These results indicate that storage using the ZECC method is good for extending the shelf life of mangoes compared to storage at room temperature.

III.1.1 Mango Skin Surface

Visual observations of the mango skin's surface revealed that ZECC storage was better compared to room temperature storage. Mango fruits stored in ZECC had smoother skin (not wrinkled) than mango fruits stored at room temperature, which had wrinkled skin surface. The absence of wrinkles in mangoes stored at ZECC is due to the relative humidity (RH) in a good storage room, which is between 80% and 98.04 percent, as opposed to room temperature, which has a relative humidity of 50% to 56.90 percent. This is consistent with Muchtadi (1992), who states that all varieties of mango are susceptible to cold damage in the form of dark spots, uneven ripening, and failure to produce adequate flavor and color, and that a relative humidity of 85-90 percent is required to prevent wilting and softening of various fruits and vegetables (Muchtadi 1992).

The room temperature is higher than the temperature in the ZECC. ZECC has a temperature range of 24-25°C, while the ambient temperature ranges from 26-31°C. Mango fruit stored at room temperature transpired and respired at a faster rate than mango stored in ZECC, causing the mango skin to wrinkle. Because respiration rate is related to the rate of quality deterioration, it can be used to estimate the shelf life of fruit after harvest. As stated by Rizkia (2004) that the slower the rate of respiration, the longer the fruit can be stored in its fresh state; conversely, the faster the rate of respiration, the shorter the shelf life (Rizkia 2004).

III.1.2 Skin color

Mangoes are generally observed visually by observing how clearly the color change from green to yellow appears on the mango skin. Mangoes stored at room temperature and in ZECC without treatment/washing (control), as well as those washed with water and detergent + $\text{Ca}(\text{OH})_2$ exhibited no discernible color changes. On the sixth day of observation, the color changed to a slight yellow hue. This color change occurs because mangoes, as climacteric fruits, accelerate the ripening process during storage. The maturation process that occurs concurrently with the breakdown of chlorophyll, resulting in the appearance of other color pigments such as yellow and red, causing the green color to degrade. This is in line with El-Zeftawi *et al.*, (1988), who stated that the level of chlorophyll content in green fruit decreases during the storage, other pigments begin to appear, turning the fruit yellow or orange (El-Zeftawi *et al.* 1988).

III.1.3 Sap and Dirt

For mango fruit washed with water, on day 6 DAW (day after washing), there were still remnants of sap attached to the surface of the mango fruit skin, although they were not particularly noticeable. However, there were a few lenticel spots and a change in color at the fruit's base on day 6 DAW (day after washing) until the 8th day of DAW. While mangoes treated with 1% detergent + 0.25 percent $\text{Ca}(\text{OH})_2$ can visually remove sap, the treatment was more effective at 1% + $\text{Ca}(\text{OH})_2$ 0.5 percent detergent immersion, which resulted in samples of mango fruit being more free of sap and dirt, resulting in a smoother surface with no noticeable changes up to 8 DAW. This is because 1% detergent binds to oil and effectively removes or lifts dirt. Until the eighth day after DAW mango was treated with 1% detergent and 0.5 percent $\text{Ca}(\text{OH})_2$, no lenticel or fungal spots appeared at the base or on the surface of the fruit skin. The surface is smoother and burn-free because the detergent's surfactant active ingredients can remove the oil contained in the sap. Alkaline $\text{Ca}(\text{OH})_2$ solution can neutralize the acid in the sap attached to the golek mango cultivar's skin. This is consistent with Ahmad, S *et al.* (2017)'s finding that the 1% + $\text{Ca}(\text{OH})_2$ 0.5 percent detergent treatment resulted in a lower mean score for reducing lenticel spots at 2 to 14 DAW when compared to the control (Ahmad *et al.* 2017). In accordance with Taqiyah (2015), a combination of detergent and $\text{Ca}(\text{OH})_2$ is capable of removing sap and oil from the surface of the Gedong mango skin (Taqiyah 2015).

III.2 Second Phase of Research

The second stage of this study involved determining the quality and shelf life of mangoes while they were stored. Mangoes that received the best washing treatment (1 percent detergent + 0.5 percent $\text{Ca}(\text{OH})_2$) were then given packaging treatment (using Polypropylene (PP) plastic and without packaging) and then analyzed for quality. Mangoes packaged with Polypropylene (PP) plastic can be stored in ZECC for 21 days, whereas mangoes packaged without Polypropylene plastic have a shelf life of only 18 days.

III.2.1 Weight Loss

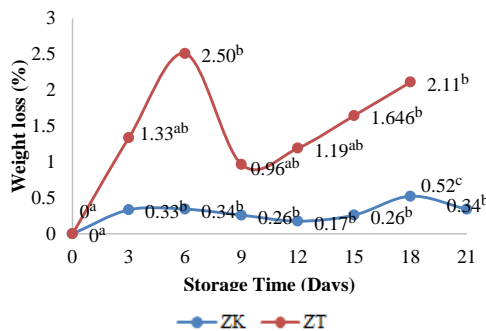


Figure 1. The weight loss of Mangoes During Storage. Values followed by different letters indicate treatment results that are significantly different ($p < 0.05$).

The results of weight loss analysis are summarised in Fig 1. During storage, the mango fruit's weight loss tends to increase. Unpackaged mangoes (ZT) lost approximately twice as much weight

as packaged mangoes (ZK). This means that when packaging is used in combination with the ZECC storage technique, mangoes lose less weight. Unpackaged mangoes experienced a greater increase in weight loss due to a high evaporation rate (transpiration), whereas packaged mangoes experienced less water evaporation during storage. Water loss results in withering and shrinking. This is consistent with Winarno (2002), who states that the amount of water in foods determines their freshness, appearance, and durability (Winarno 2002). If some of the water in the food evaporates, weight loss occurs, reducing the food's freshness, appearance, and durability.

In addition to transpiration, weight loss is also influenced by the respiration process of mango fruit. Carbon loss can occur during the respiration process. Carbon compounds contained in the sugar in mangoes will bind and react with oxygen which will produce simple volatile compounds, namely water vapor and carbon dioxide so that the fruit will lose its weight. So in this case it is known that the respiration process can be suppressed by a combination of packaging and storage in ZECC. This is in accordance with the opinion of Syafutri et al., (2006), which states that the process of fruit respiration can be suppressed by combining packaging and storage at low temperatures (Syafutri, Pratama, and Saputra 2006).

III.2.2 Hardness Level

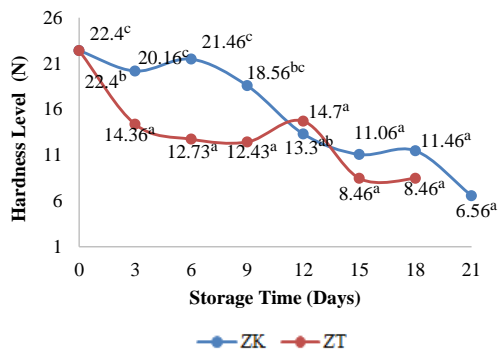


Figure 2. The Hardness Level of Mango Fruit During Storage. Values followed by different letters indicate treatment results that are significantly different ($p < 0.05$).

The Fig. 2 provides a quantitative analysis of the hardness level of mango. The ripening process of mangoes during storage results in changes in the level of mango fruit hardness. The ripening process in mangoes occurs concurrently with the conversion or degradation of protopectin to pectin, resulting in a decrease in cell wall rigidity. Mangoes without packaging treatment (ZT) had a greater loss of hardness than mangoes with packaged treatment (ZK). This is due to the fact that unpackaged mangoes have a higher respiration rate and a higher enzyme activity. The more actively these enzymes are, the softer the texture of the fruit. Meanwhile, the rapid rate of respiration causes the fruit tissue to rupture, resulting in the mango becoming soft. The mango with packaging treatment (ZK) can reduce the amount of oxygen received, thereby slowing the respiration process (maintained). This is consistent with Syafutri et al. (2006), who states that the decrease in hardness is also a result of the respiration and transpiration processes (Syafutri et al. 2006). The respiration process results in the breakdown of carbohydrates into simple compounds and tissue rupture, resulting in the mango becoming soft, whereas the transpiration process results in water evaporation, resulting in the mango becoming wilted.

III.2.3 Vitamin C levels

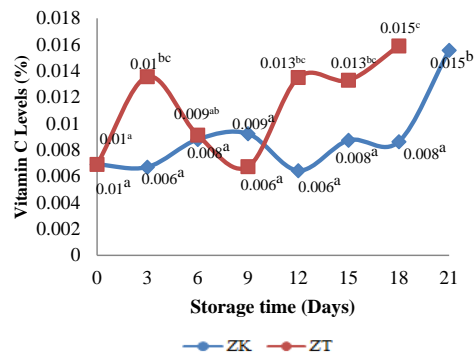


Figure 3. Vitamin C Levels of Mangoes During Storage. Values followed by different letters indicate treatment results that are significantly different ($p < 0.05$).

The levels of vitamin C (ascorbic acid) of mangoes during storage in ZECC tend to vary, both packaged in polypropylene plastic and mangoes without packaging as can be seen in Fig 3. The significant increase in vitamin C levels of unpackaged mangoes until the end of storage was in line with the faster ripening process of mangoes compared to packaged mangoes. This is in accordance with Pantastico (1986), which states that ripe fruit will increase in acidity, and this increase occurs simultaneously with the climacteric pattern, while vitamin C levels will decrease when the maximum point of increase has been exceeded (withering stage)(Pantastico 1986). The ripening process of unpackaged mangoes is faster because the respiration process is greater than that of packaged mangoes. Mango packaging can regulate/minimize the respiration process of the fruit so that the freshness of the mango can be maintained. This is in accordance with Park et al., (2004), which states that Polypropylene (PP) plastic has high permeability properties which can regulate the rate of atmospheric absorption or respiration rate which can maintain fruit freshness longer(Park, Kim, and Yun 2004). The results of analysis of variance showed that mango without packaging treatment and mango with packaging treatment had a significant effect on vitamin C levels during storage. This is indicated by the value of vitamin C which was initially low and then increased until the end of storage. The increase or decrease in vitamin C is because the vitamin is unstable, easily oxidized when exposed to air (oxygen) and this process can be accelerated by storage temperature. This is in accordance with Tannenbaum (1976), stating that the reduction of O_2 will inhibit the degradation of ascorbate into dehydroascorbic acid and H_2O_2 (Tannenbaum 1976). The resulting H_2O_2 will cause autoxidation so that it will increase the damage of vitamin C.

III.2.4 Total Acid

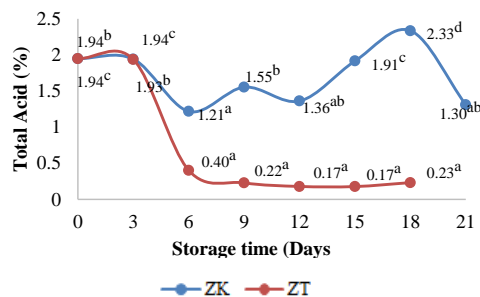


Figure 4. Total Acid Level of Mango Fruit During Storage. Values followed by different letters indicate treatment results that are significantly different ($p < 0.05$).

The Fig. 4 outlines the results of the total acid level. The total acid value of mango in ZECC storage, both packaged and unpackaged, tends to decrease, though the trend is variable. The percentage of total acid in the fruit decreases as the fruit is stored. The decrease in the percentage of total acid is due to the respiration process's use of organic acids, as well as the use of organic acids by microbes in energy-consuming activities. This energy is obtained through the breakdown of the nutrients found in food. Organic acids are converted to sugars during the respiration process. Khairi *et al.* (2017) found in their research that the fruit's decreased organic acid value indicated that the fruit's ripening metabolism was functioning normally [Khairi *et al.* (2017)].

Total acid in mangoes that were not packaged (ZK) degraded more rapidly than in packaged mangoes (ZK). This is due to the respiration process of unpackaged mangoes. Syafutri *et al.* (2006) state that when mangoes are not packaged, the respiration process cannot be minimized due to the abundant O_2 in the environment (Syafutri *et al.* 2006).

III.2.5 Total Dissolved Solids (TDS)

In Fig. 5 We present a detailed evaluation of total dissolved solids. Mangoes' total dissolved solids (packaged and unpackaged) exhibit a fluctuating graph. Unpackaged mangoes (ZT) underwent a maximum ripening process, as indicated by the percentage of TDS value increasing significantly at first and then gradually decreasing until the end of storage. The increase in TDS is a result of starch hydrolysis during ripening process. While the decrease in TDS occurs as a result of the abundant O_2 available in the environment, it may be which contributes to the respiration process. Thus, glucose as the result of starch hydrolysis then was consumed during the respiration process, resulting in a rapid decrease in the sugar content of the fruit. Pantastico (1986) confirms this by stating that during ripening, starch is hydrolyzed into simple compounds that serve as a source of energy during the respiration process (Pantastico 1986). At this point, the sucrose has been converted back to glucose and fructose. The decrease in total sugar content of unpackaged mangoes occurred as the mango fruit began to ripen, at which point the starch content began to decrease and the activity of the invertase enzyme decreased, resulting in a decrease in sugar content. The mango with packaging (ZK) has the ability to maintain the fruit's ripening process, as indicated by the predominant fluctuating TDS value. This demonstrates that by combining packaging and storage in ZECC, the rate of decrease in the percentage of TPT in mangoes can be slowed.

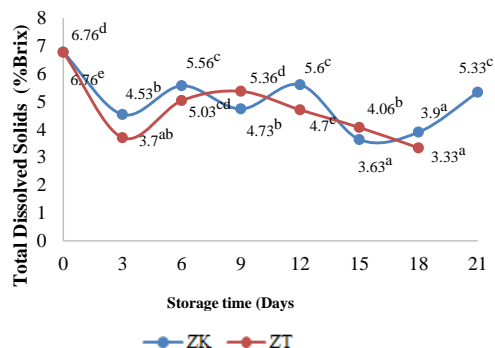


Figure 5. Total Dissolved Solids of Mango Fruit During Storage. Values followed by different letters indicate treatment results that are significantly different ($p < 0.05$).

This variable total dissolved solids value is also a result of the fruit's non-uniform maturity level. Non-uniform fruit ripeness causes abnormal respiratory activity so that the breakdown process of simple sugars varies. In general, changes in total dissolved solids content increased at the maximum point of storage and then decreased until the fruit began to rot on the final day of storage. This is consistent with Biale and Young's (1971) observation that the general trend is for a rapid increase in sugar content followed by a decline; in climacteric fruit, this condition becomes a marker (Biale and Young 1971).

III.2.6 Degree of Acidity (pH)

According to the Fig.6, mango fruit are acidic, with a pH value ranging between 2 and 6 during storage. The ripening of mangoes alters the pH value of the fruit. Without packaging treatment (ZT), mango matured rapidly (maximum), increasing the pH value. It is not the case with packaged mangoes (ZK), as their ripening process is slowed, resulting in a stable pH value throughout storage. As the mango ripens, the acid content decreases while the simple sugars increase, as indicated by the decrease in total acid content. The pH value is directly proportional to vitamin C levels and inversely proportional to total acidity. This is consistent with Khairi *et al.*, (2017), who state that changes in pH indicate changes in the composition of the fruit's cell fluid as it matures; the pH value that tends to be high is related to relatively high ascorbic acid (vitamin C) levels during storage; this change indicates that the fruit's metabolism affects the pH value (Khairi *et al.* 2017).

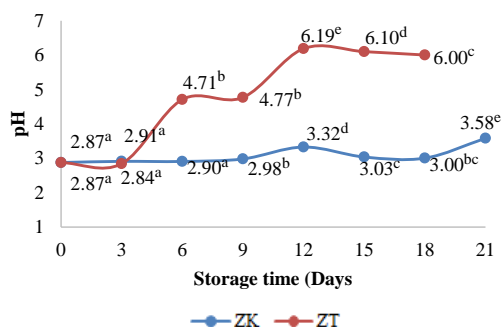


Figure 6. pH Value (Degree of Acidity) Mango Fruit During Storage. Values followed by different letters indicate treatment results that are significantly different ($p < 0.05$).

III.2.7 Water content

The water content of mangoes stored in the ZECC method varied slightly during storage that we can see in Fig. 7. When compared to unpackaged mangoes, packaged mangoes (ZK) are able to maintain changes in water content during storage. This is because PP packaged mangoes have a high permeability, which minimizes changes in water content during storage. This is consistent with

Schwartz (2009), who states that because of the packaging, ambient air cannot easily enter the material, thereby inhibiting the process of water exchange during storage(Schwartz 2009).

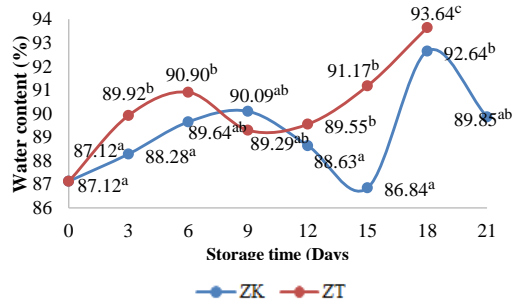


Figure 7. Water Content of Mangoes During Storage. Values followed by different letters indicate treatment results that are significantly different ($p < 0.05$).

Due to the high humidity in ZECC storage, which reached 80-90 percent, mango fruit experienced an increase and decrease in water content during storage. Due to the high humidity level in the ZECC room, moisture absorption from the environment into the stored mango is possible. The longer the storage time, the higher the water content will remain. According to Herawati (2008), a significant factor influencing the decline in the quality of food products is changes in the product's water content, which can be influenced by the room's temperature and humidity during storage (Herawati 2008). This opinion is backed up by Retnani et al., (2009), who state that the high humidity of the storage room can result in the absorption of water vapor from the air into the foodstuffs, resulting in an increase in water content (Retnani et al. 2009).

Additionally, the increase in water content during storage is a result of the mangoes' respiration process. During storage, the fruit undergoes a ripening process that includes the conversion of starch to simple sugars ($C_6H_{12}O_6$). These simple sugars then interact with the oxygen (O_2) in the chamber, increasing the rate of water (H_2O) formation in the fruit. This is consistent with Rizkia (2004), who states that one of the causes of changes in the water content of fruit is the respiration process, during which water is formed as a result of sugar reorganization into simpler compounds.

III.2.8 Color

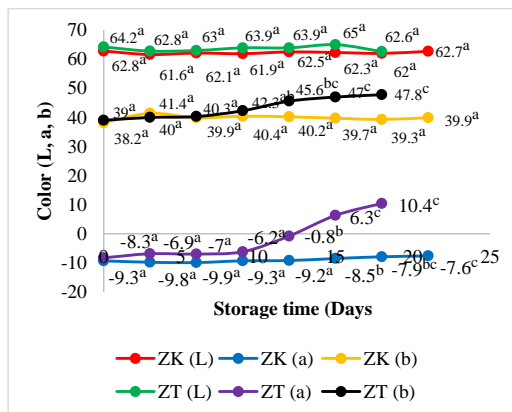


Figure 8. Analysis of Mango Skin Color During Storage. Values followed by different letters indicate treatment results that are significantly different ($p < 0.05$).

Based on the results in Fig. 8, We make the following observations. The L^* value indicates the brightness level of the mango fruit, which indicates the reflected light that produces achromatic colors of white, gray and black, ie from a value of 0 (black) – 100 (white). The L^* value of unpackaged and packaged mangoes had a very small decrease in lightness value during storage. The

range of changes in the L* value from 65-62 indicates a slight decrease in brightness level during storage. The longer the fruit is stored, the lower the brightness level of the mango. According to Ahmad et al., (2014), that the brightness level of the color will decrease which will be directly proportional to the longer the shelf life, the fruit will lead to spoilage in the end(Ahmad, Darmawati, and Refilia 2014). The decreasing brightness level of the mango skin color is caused by changes in the chlorophyll content of the fruit. This is in accordance with the statement of Syafutri et al., (2006), which states that the reduced level of color brightness in fruit during storage is caused by reduced chlorophyll content in fruit skins and the appearance of carotenoids(Syafutri et al. 2006).

The a* value is a value that shows the gradation of green to red. A mixed red-green chromatic color with a value of +a* (positive) from 0 to +80 for red and a value of -a* (negative) from 0 to -80 for green. The a* value of mango tends to increase during the storage process. Mangoes tend to be green, indicated by an a* value below 0, but the longer the storage time, the color of the fruit moves to red. The significant increase in a* value was caused by the high respiration rate of unpackaged mangoes so that the degradation of chlorophyll was also rapid which had the effect of accelerating the synthesis of pigment (color change) of the fruit. This is in accordance with the opinion of Masfufatun *et al.* (2009), which states that a high respiration rate will also cause chlorophyll degradation and pigment synthesis to be fast, consequently accelerating color changes(Masfufatun, Kumala, and Rahayuningsih 2009).

The b* value indicates the color gradation to yellow. A mixed blue-yellow chromatic color with +b* (positive) value from 0 to +70 for yellow and -b* (negative) value from 0 to -70 for blue. Based on the figure 8, it shows that unpackaged mangoes have a slowly increasing b* value during storage compared to packaged mangoes whose b* values tend to be stable until the end of storage. The results of the measurement of the b* value show that the longer the storage, the yellow color of the mango will be clearer. The increasing b* value in unpackaged mangoes indicates that the fruit is getting more mature than the packaged mangoes during storage. This is in accordance with the statement of Kusumiyati et al., (2018), which states that the longer the storage, the yellow color of the mango is more clearly marked by the higher the mean b* value. The higher the b* value in the mango can be indicated the higher the ripeness level of the fruit(Kusumiyati et al. 2018).

- Deleted: a
- Deleted: a
- Commented [U1]: No underline

III.2.9 Organoleptic test

III.2.9.1 Color

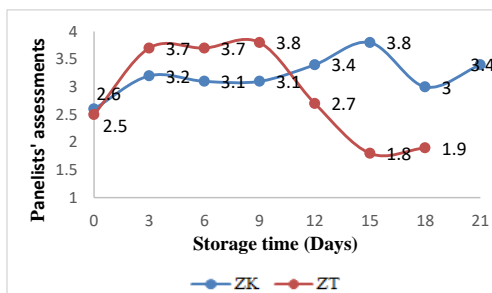


Figure 9. Results of Organoleptic Testing on Mango Color in ZECC Storage

The Fig. 9 summarises and discusses the main findings of the of organoleptic color. The changes in panelists' assessments of organoleptic color parameters in mangoes were due to the nature of mangoes undergoing post-harvest ripening (after harvesting), specifically that the color will change during the storage process due to chlorophyll degradation into other pigments. The panelists' assessment of mangoes with packaging treatment (ZK) tended to remain stable until the end of storage, with an average value of 3 (slightly similar), whereas mangoes without packaging (ZT) maintained an average value of 4 (similar) until the ninth day of storage, when it decreased until the end of storage. This demonstrates that mangoes treated with packaging can help preserve or

delay the color change of mangoes stored in ZECC. Packaging treatment on mangoes can slow the respiration process, resulting in a slower color change and maturation and aging process. This is consistent with Ali (2017), who states that a faster respiration rate can accelerate the senescence process, which results in a more rapid color change.

III.2.9.2 Aroma

The panelists' evaluations of the mango aroma parameters revealed a range of results but a consistent pattern of increasing and then decreasing until the end of storage. In terms of fruit aroma, panelists prefer the unpackaged aroma of mango fruit as can be seen in Fig. 10.

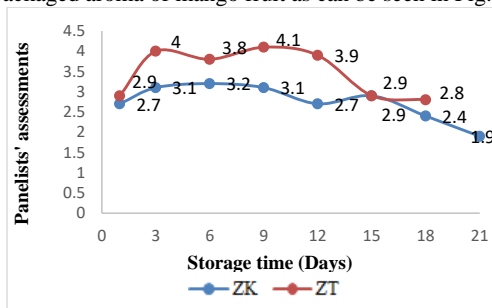
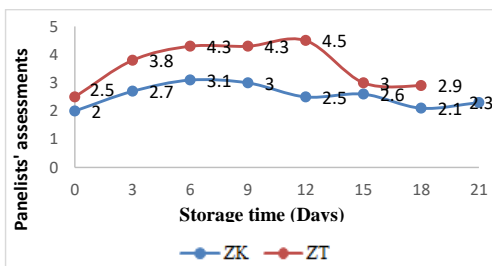


Figure 10. Results of Organoleptic Testing on Mango Aroma in ZECC Storage

The high acceptance of unpackaged mango aroma (ZT) is a result of the increasing ripening process (perfect ripening), which results in an increase in the production of volatile components. While the packaged mango (ZK) took longer to decompose, the panelists generally disliked it due to the incomplete ripening process, which resulted in a low flavor. This is consistent with Muchtadi (1992), who stated that ripening typically results in an increase in the content of simple sugars, which imparts a sweet flavor, as well as an increase in the production of volatile substances, which imparts a distinctive fruit flavor.

III.2.9.3 Taste



Gambar 11. Results of Organoleptic Testing on Mango Taste in ZECC Storage

The results of the taste are summarised in Fig. 11. The results of organoleptic taste on mangoes stored at ZECC showed that the panelists' assessment of fruit taste increased and then decreased until the end of storage. The range of values between 3-5 (based on the graph) shows that the panelists' assessment of unpackaged mangoes (ZT) is dominantly preferable to mangoes with packaged treatment (ZK) with a value of 2-3. The high rating for unpackaged mangoes is because the mangoes undergo an even ripening process during storage, resulting in a distinctive taste and good color which are preferred by panelists (Ali 2017). The sweet taste is due to the change in the starch content of the fruit during storage. This is in accordance with the statement of Mulyati (2012), that changes during the ripening process are changes in starch and fat reserve materials into various sugars (Mulyati 2012). The mango with packaging (ZK) undergoes a slow ripening process due to its low respiration rate in the presence of packaging, but it takes longer to decay or damage in ZECC storage.

IV.2.9.4 Texture

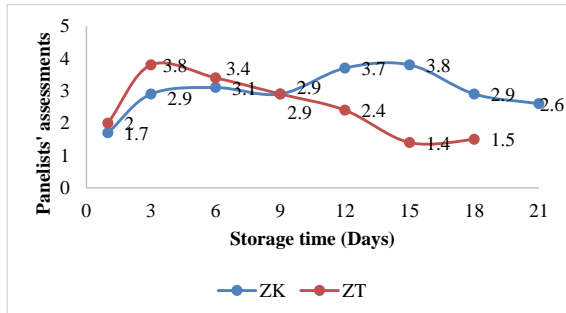


Figure 12. Results of Organoleptic Testing on Mango Texture in ZECC Storage

Fig. 12 illustrate results of mango's texture. Panelists determined that mango with packaged treatment (ZK) (mean value 3-4) was preferable in terms of texture because the level of hardness did not decrease significantly (soft), as opposed to mango without packaged treatment (ZT) (mean value 2-3). The texture began as hard, which the panelists disliked, then softened slightly, which the panelists liked, and finally became extremely soft due to damage/rotting, which the panelists disliked. When the qualitative (organoleptic test of texture parameters) analysis of mango fruit is combined with quantitative analysis (with a penetrometer), it is discovered that the level of hardness (the process of hardness decreasing) is directly proportional during storage.

Mangoes' softening texture is caused by the ripening process that occurs during storage. Maturation occurs concurrently with the conversion or degradation of insoluble protopectin to soluble pectin. The reshuffle occurs as a result of the action of enzymes such as pectin methyl esterase, which softens the fruit. Protopectin levels in the fruit decrease as the fruit ripens, while pectin levels increase. This is in accordance with Johansyah *et al.*, (2014), that as fruit ripens and stores, some of the water-insoluble protopectin converts to water-soluble pectin, reducing the cohesion of the cell walls that connect cells, resulting in a decrease in texture or fruit hardness and the fruit becoming soft (Johansyah and Kusdiantini 2014). Additionally, the rate of respiration has an effect on the degree of hardness or texture. Unpackaged mangoes with a high respiration rate cause the fruit's tissue to rupture and enzyme activity to accelerate, resulting in a softer fruit texture. The mango with packaging treatment (ZK) can reduce the amount of oxygen received, thereby slowing the respiration process (maintained).

III.2.10 Microbial Analysis (Yeast Mold Count)

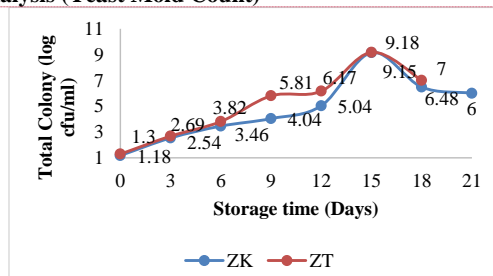


Figure 13. Mold and Yeast cell count on Mangoes During Storage in ZECC

According to the Fig.13, the results of microbial analysis (mold and yeast counts) on mango fruit storage in ZECC indicated that yeast mold growth continued to increase and then decreased gradually until the end of storage. Microbial growth (mold and yeast) that began low/small and then increased to a maximum growth peak on the 15th day generally indicated that the mangoes' quality deteriorated during storage and gradually entered the senescence phase. This also demonstrates that mangoes with a relatively high sugar content and a low pH provide an ideal environment for molds and yeasts to grow to their maximum growth capacity during storage. This is consistent with Seema

Commented [U2]: The point must be 3.2.10. In galley proof, without point

R (2015) statement that fruit with a high sugar content and a low/acidic pH (pH range between 3-8) promotes the growth of fungi (mold/yeast) after the fruit is harvested (Rawat 2015).

Mango without packaging (ZT) exhibited a greater increase in the growth of the dominant mold/yeast than mango with packaging (ZK). This demonstrates that by combining calcium hydroxide washing with packaging on mangoes stored in ZECC, the rate of microbial growth can be slowed or suppressed, thereby extending the fruit's life phase. Certain microbes require oxygen to grow, which can be suppressed through packaging. This is consistent with the opinion of Mulyawanti *et al.* (2017), who state that treating fruit with packaging technology can suppress the air activity required by microbes, thereby slowing the growth rate of pathogenic microbe [Mulyawanti *et al.* (2018)].

IV. Conclusions

It can be concluded that analysis of the quality of golek mango (*Mangifera indica* L.) physically, chemically, microbiologically, and sensory in the Zero Energy Cool Chamber (ZECC) storage technique shows that ZECC can maintain optimal fruit quality through a washing treatment process (chemically) in combination with packaging. In addition, the Zero Energy Cool Chamber (ZECC) storage method with a combination of washing and packaging treatments is effective in maintaining the quality of mangoes up to 21 days of storage.

V. Acknowledgment

This research was funded by the Directorate General of Research and Development, Ministry of Research, Technology and Higher Education, Republic of Indonesia, through LPPM Unhas : Penelitian Terapan 2020 Number 7 /E1/KP.PTNBH/2021.

References

- Ahmad, Sutopo, Roedhy Poerwanto, and Suryo Wiyono. 2017. "Keefektifan Bahan Pencuci Dan Pencegah Penyakit Terhadap Kualitas Buah Mangga CV. Gedong Gincu Dan Arumanis (The Effectiveness of Washing Materials and Disease Protecting Agent on the Quality of Mango Fruit Cv. Gedong Gincu and Arumanis)." *Jurnal Hortikultura* 27(2):253–60.
- Ahmad, Usman, Emmy Darmawati, and Nur Rahma Refilia. 2014. "Kajian Metode Pelilinan Terhadap Umur Simpan Buah Manggis (*Garcinia Mangostana*) Semi-Cutting Dalam Penyimpanan Dingin." *Jurnal Ilmu Pertanian Indonesia* 19(2):104–10.
- Ali, Kamilia Nur Yaumil. 2017. "Mutu Buah Mangga (*Mangifera Indica* L.) Dan Tomat (*Lycopersicum Esculentum* Mill.) Yang Disimpan Pada ZECC (Zero Energy Cool Chamber)." Universitas Hasanuddin.
- Biale, J. B. and R. Young. 1971. *The Avocado Pear. Dalam Hulme, A.C. The Biochemistry of Fruit and Their Produce*. London: Academic Press.
- Dirpan, A. 2019. "The Quality of Tomato (*Lycopersicum Esculentum* Mill.) Stored on ZECC (Zero Energy Cool Chamber)." P. 12012 in *IOP Conference Series: Earth and Environmental Science*. Vol. 270. IOP Publishing.
- Dirpan, Andi. 2018. *ZECC (Zero Energy Cool Chamber) Penyimpanan Dingin Yang Murah Dan Ramah Lingkungan Untuk Memperpanjang Masa Simpan Buah Dan Sayur Setelah Panen*. Makassar: Universitas Hasanuddin.
- Dirpan, Andi, Muhammad Tahir Sapsal, Abdul Kadir Muhammad, Mulyati M. Tahir, and

- Rahimuddin. 2017. "Evaluation of Temperature and Relative Humidity on Two Types of Zero Energy Cool Chamber (ZECC) in South Sulawesi, Indonesia." *IOP Conference Series: Earth and Environmental Science* 101:012028.
- El-Zeftawi, B. M., L. Brohier, L. Dooley, F. H. Goubran, R. Holmes, and B. Scott. 1988. "Some Maturity Indices for Tamarillo and Pepino Fruits." *Journal of Horticultural Science* 63(1):163–69.
- Herawati, Heny. 2008. "Penentuan Umur Simpan Pada Produk Pangan." *Jurnal Litbang Pertanian* 27(4):124–30.
- Islam, M. P. and T. Morimoto. 2015. "ScienceDirect Evaluation of a New Heat Transfer and Evaporative Design for a Zero Energy Storage Structure." *Solar Energy* 118:469–84.
- Islam, M. P., T. Morimoto, and K. Hatou. 2013. "Dynamic Optimization of inside Temperature of Zero Energy Cool Chamber for Storing Fruits and Vegetables Using Neural Networks and Genetic Algorithms." *Computers and Electronics in Agriculture* 95:98–107.
- Johansyah, Afrazak and Endang Kusdiantini. 2014. "Pengaruh Plastik Pengemas Low Density Polyethylene (LDPE), High Density Polyethylene (HDPE) Dan Polipropilen (PP) Terhadap Penundaan Kematangan Buah Tomat (*Lycopersicon Esculentum*. Mill)." *Anatomi Fisiologi* 22(1):46–57.
- Khairi, Amalya Nurul, Affan Fajar Falah, and Agung Putra Pamungkas. 2017. "Analisis Mutu Pascapanen Melon (*Cucumis Melo* L.) Kultivar Glamour Sakata Selama Penyimpanan." *CHEMICA: Jurnal Teknik Kimia* 4(2):47–52.
- Kusumiyati, Farida, Wawan Sutari, and Syariful Mubarak. 2018. "Kualitas Buah Mangga Selama Penyimpanan Pada Keranjang Anyaman Bambu Dengan Identifikasi Ruang Warna L*, A* Dan B." *Kultivasi* 17(2):628–32.
- Masfufatun, Widaningsih, N. Kumala, and T. Rahayuningsih. 2009. "Pengaruh Suhu Dan Waktu Penyimpanan Terhadap Vitamin c Dalam Jambu Biji (*Psidium Guajava*)." *Universitas Wijaya Kusuma, Surabaya*.
- Muchtadi, Deddy. 1992. *Fisiologi Pasca Panen Sayuran Dan Buah-Buahan: Petunjuk Laboratorium*. Institut Pertanian Bogor.
- Mulyati. 2012. *Sayur-Sayuran, Buah-Buahan Penanganan Dan Pengolahannya*. Makassar: CV. Indo media.
- Mulyawanti, Ira, Enrico Syaefullah, and Dwi Amiarsi. 2018. "Teknologi Pengemasan Atmosfir Termomodifikasi (Modified Atmosphere Packaging/Map) Dan Vakum Pada Buah Durian."
- Pantastico, E. B. 1986. *Fisiologi Pascapanen, Penanganan Dan Pemanfaatan Buah-Buahan Dan Sayur-Sayuran Tropika Dan Subtropika (Terjemahan Kamariyani 1997)*. Yogyakarta: Gajah Mada University Press.
- Park, T., Y. A. Kim, and J. Yun. 2004. "The Need for Collaboration in the Supply Chain For Successful Direct Shipments." in *Proceedings of the Thirty-Third Annual Meeting of the Western Decision Sciences Institute*.
- Rawat, Seema. 2015. "Food Spoilage: Microorganisms and Their Prevention." *Asian Journal of Plant Science and Research* 5(4):47–56.
- Retnani, Y., W. Widiarti, I. Amiroh, L. Herawati, and K. B. Satoto. 2009. "Daya Simpan Dan Palatabilitas Wafer Ransum Komplit Pucuk Dan Ampas Tebu Untuk Sapi Pedet." *Media Peternakan* 32(2):130–36.
- Rizkia. 2004. "Kajian Laju Respirasi Dan Perubahan Mutu Buah Mangga Gedong Gincu Selama Penyimpanan Dan Pematangan Buatan." Institut Pertanian Bogor.
- Schwartz, Naomi. 2009. "Pengaruh Jenis Bahan Pengemas Terhadap Kualitas Cabe Merah Segar Selama Penyimpanan Dingin." Universitas Sumatra Utara.

Deleted: Kusumiyati,

Deleted: Farida

- Syafutri, Merynda I., F. Pratama, and D. Saputra. 2006. "Sifat Fisik Dan Kimia Buah Mangga (Mangifera Indica L.) Selama Penyimpanan Dengan Berbagai Metode Pengemasan." *Jurnal Teknologi Dan Industri Pangan* 17(1):1–11.
- Tannenbaum. 1976. *Vitamins and Mineral*. New York (US: Mercel Dekker.
- Taqqiyah, Affifah. 2015. "Pengaruh Penambahan Fungisida Pada Bahan Pencuci Serta Suhu Penyimpanan Terhadap Peningkatan Kualitas Mangga. (Mangifera Indica L.)"
- Winarno. 2002. *Fisiologi Lepas Panen Produk Hortikultura*. Bogor: M-Brio Press.



Andi Dirpan <dirpan@unhas.ac.id> Nov 18, 2021, 6:31 PM

to ram

Dear Dr. Ram

Thank you for your email.

Please check page 1 : key word and page 10 : should be new point 3.2.10

best regard

Andi

Paper Published



ORIGINAL ARTICLE

EXTENDING OF MANGO (*MANGIFERA INDICA* L.) SHELF LIFE WITH COMBINATION OF ZERO ENERGY COOL CHAMBER (ZECC) STORAGE TECHNOLOGY, WASHING AND PACKAGING

Andi Dirpan*, Muhammad Tahir Sapsal, Mulyati M Tahir, Muspirah Djalal and Ashabul Firdaus

Department of Agricultural Technology, Hasanuddin University, Makassar 90245, Indonesia.

E-mail: dirpan@unhas.ac.id

Abstract: Mangoes suffer up to a 20%-50% shrinkage, loss, and quality damage as a result of improper harvest and post-harvest handling, as well as poor storage conditions. The presence of a post-harvest technology system of Zero Energy Cool Chamber (ZECC) storage combined with pre-handling treatment (washing and packaging) is one method of minimizing damage and extending the shelf life of mangoes. This study aimed to determine the mango golek's quality and shelf life by using ZECC in combination with washing and packaging. This study used a completely randomized design (CRD) with factorial patterns, specifically factor A (storage type) and factor B (packaging and without packaging). The study's observation parameters were divided into two stages, with stage 1 consisting of physical parameters and stage 2 consisting of chemical, microbiological, and sensory parameters. According to preliminary research, the best treatment is washing with 1% detergent + 0.5 percent Ca(OH)₂, which results in a smoother skin surface, less noticeable discoloration, and a cleaner surface free of sap and dirt. Physical, chemical, microbiological, and sensory analysis of mango golek (*Mangifera indica* L.) demonstrates that the ZECC storage technique can maintain fruit quality optimally in combination with washing (chemical) and packaging treatment processes and it can effectively protect the mango golek's quality for up to 21 days.

Key words: Fruit-quality, Postharvest technology, Cool chamber, Shelf life.

Cite this article

Andi Dirpan, Muhammad Tahir Sapsal, Mulyati M Tahir, Muspirah Djalal and Ashabul Firdaus (2021). Extending of mango (*Mangifera indica* L.) Shelf Life with combination of Zero Energy Cool Chamber (ZECC) storage technology, washing and packaging. *International Journal of Agricultural and Statistical Sciences*. DocID: <https://connectjournals.com/03899.2021.17.1553>

1. Introduction

Indonesia possesses immense natural resource potential, particularly in horticultural crops like mango. According to the Indonesian Central Statistics Agency, mango production reached 2,431,329 tons per year in 2014 and 2,178,833 tons per year in 2015, a decrease of 10.39 percent. Mango productivity continues to be harmed by improper harvesting and post-harvest handling, which degrades the quality of the mangoes. Additionally, storage conditions are insufficient during agricultural product distribution and marketing, resulting in fruit depreciation. According to research conducted in developing countries, improper harvesting and post-harvest handling can result in fruit yield losses ranging

from 20% to 50% [Dirpan *et al.* (2017)].

Cold storage is one technique for post-harvest handling. However, rural areas, which are typically agricultural centers, have severe shortages of cold storage, such as refrigerators. Additionally, the high operational costs associated with cold storage present a significant barrier to farmers employing post-harvest handlers. Additionally, it produces freon, an environmentally hazardous chemical [Dirpan *et al.* (2017)]. In light of the aforementioned issues, we require an energy-free (zero energy) cold storage system that is also affordable (low cost) and environmentally friendly (ecofriendly), one of which is the Zero Energy Cool Chamber (ZECC) [Islam and

Morimoto (2015)].

The Zero Energy Cool Chamber (ZECC) is a cost-effective and environmentally friendly method of storing fruits and vegetables following harvest. Due to the fact that ZECC does not require electricity to operate, it is frequently referred to as an environmentally friendly fruit and vegetable storage system [Dirpan (2019), Islam *et al.* (2013)]. Additionally, this storage system is cost effective due to the fact that it makes use of readily available materials such as bricks, sand, plastic roofs and water [Dirpan *et al.* (2017), Islam *et al.* (2013)].

Recent years have seen an increase in research on fruit and vegetable storage methods utilizing ZECC, as demonstrated by Ali (2017) and Dirpan (2018) studied examining the quality of mangoes and tomatoes stored in ZECC [Ali (2017), Dirpan (2008)]. However, because fungi grew around the mangoes in the aforementioned studies, ZECC was used in conjunction with pre-handling treatments such as washing and packaging to minimize the possibility of mold and yeast growth and to extend the shelf life of the golek mango. As a result, the purpose of this research were: to determine the physical, chemical, microbiological and sensory characteristics of mango golek stored in a ZECC (Zero Energy Cool Chamber) in combination with washing and packaging processes and to determine the shelf life of mangoes stored in a ZECC (Zero Energy Cool Chamber) in combination with washing and packaging processes.

2. Materials and Methods

2.1 Date and Location of Research

This research was conducted from July to November 2019 at the Food Processing Laboratory and the Chemical Laboratory of Food Quality Analysis and Supervision of the Food Science and Technology Study Program, Department of Agricultural Technology, Faculty of Agriculture, Hasanuddin University, as well as at the Research Activity Center (PKP) building and Lecturer Housing Unhas Tamanlarea, Makassar.

2.2 Instruments and materials

The tools used in this research include a zero energy cool chamber (ZECC), polypropylene plastic packaging, fruit racks, temperature and relative humidity sensors, hoses, scales, analytical scales and moisture, analyzer, colorimeter, penetrometer, digital hand refractometer, pH meter, stirring rod, beaker, erlenmeyer flask, volumetric flask, dropper pipette, volume pipette, petri

dish, autoclave, bulb, micropipet, test tube, tube rack, laminar air flow (LAF), plates, spoons, knives, rags, blenders.

Materials used in this study were 77 golek mango (main ingredient) with a maturity index of 2 (light green), aquadest, detergent, chlorine, calcium hydroxide ($\text{Ca}(\text{OH})_2$), sodium hydroxide (NaOH), iodine, indicator phenolphthalein, alcohol, buffer pH 7, mineral water, starch indicator (starch), potato dextrose agar (PDA) medium, inhibitor (chloramphenicol), cotton, and labels.

2.3 Research procedure

The research process is as follows:

2.3.1 Preliminary research

Mangoes are sorted, and then those that are not rotten or injured are selected for this research. The mango is then graded according to its maturity level. Following that, the Zero Energy Cool Chamber (ZECC) is chemically sterilized by spraying 0.5 percent chlorine + 70% alcohol. After that, the mangoes are prepared and washed using water, detergent, and $\text{Ca}(\text{OH})_2$ in accordance with the treatment method. After washing, the mangoes were air-dried and then stored in two different conditions: ZECC and room temperature.

After that, the mango fruit was observed daily for changes until the eighth day of storage.

2.3.2 Main research

The following stage is mango that has received the best treatment during the washing process (1 percent detergent + 0.5 percent $\text{Ca}(\text{OH})_2$), combined with post-harvest technology, specifically packaging techniques utilizing Polypropylene (PP) plastic, and then returned to the sterilized ZECC. Each day, the fruit is analyzed for damage, which is defined as shriveling, softening, dull skin color, the appearance of black spots on the fruit's skin, and the presence of mold at the fruit's base.

2.4 Research design

The design of the research is divided into two stages. The first stage is to determine the optimal treatment for washing mangoes using various washing ingredients, with the following treatments:

A_0 : Control (Without washing).

A_1 : Water-based cleaning.

A_2 : 1% detergent + 0.25% $\text{Ca}(\text{OH})_2$.

A_3 : 1% detergent +0.5% $\text{Ca}(\text{OH})_2$.

Following with storage in ZECC and at room

temperature, physical parameters of the fruit skin surface, color, sap and impurities were observed visually.

The next step is mango that received the best treatment during the washing process, combined with packaging techniques utilizing Polypropylene (PP) plastic. It is then analyzed every three days using a variety of observation parameters.

2.5 Data analysis

The data obtained in the second phase of the study were compiled using a completely randomized design (CRD) with a factorial pattern, namely factor A (type of storage) and factor B (packaged and unpackaged). The research was carried out with three replications.

Data processing used quantitative descriptive method, all parameters were analyzed by analysis of variance (ANOVA) with three replications. The differences for each treatment were further tested using Duncan's test. The software used for data processing is Microsoft Excel 2016 and IBM SPSS Statistics Version 23.

2.6 Observation parameter

Observation parameters in stage 1 are physical parameters of fruit skin surface, color, sap and dirt. Parameters observed in stage 2 include vitamin C, pH value, water content, total acid, total dissolved solids, weight loss, skin color, hardness test, total microbe, and organoleptic test using 15 panelists.

3. Results and Discussion

3.1 First phase of research

The results of the storage of mangoes from the preliminary study showed that mangoes stored at ZECC had better physical quality (visually) than mangoes stored at room temperature. Mangoes stored in ZECC had smoother skin, less noticeable skin discoloration until the 8th day of storage, fewer lenticel spots, and did not grow fungus on the skin surface. The fruit that was stored at room temperature with a rougher skin surface (wrinkled), slightly noticeable skin discoloration, lenticel spots began to appear on the 5th day of storage, as well as fungal growth in some mango samples. These results indicate that storage using the ZECC method is good for extending the shelf life of mangoes compared to storage at room temperature.

3.1.1 Mango Skin Surface

Visual observations of the mango skin's surface

revealed that ZECC storage was better compared to room temperature storage. Mango fruits stored in ZECC had smoother skin (not wrinkled) than mango fruits stored at room temperature, which had wrinkled skin surface. The absence of wrinkles in mangoes stored at ZECC is due to the relative humidity (RH) in a good storage room, which is between 80% and 98.04 percent, as opposed to room temperature, which has a relative humidity of 50% to 56.90 percent. This is consistent with Muchtadi (1992), who states that all varieties of mango are susceptible to cold damage in the form of dark spots, uneven ripening, and failure to produce adequate flavor and color, and that a relative humidity of 85-90 percent is required to prevent wilting and softening of various fruits and vegetables [Muchtadi (1992)].

The room temperature is higher than the temperature in the ZECC. ZECC has a temperature range of 24-25°C, while the ambient temperature ranges from 26-31°C. Mango fruit stored at room temperature transpired and respired at a faster rate than mango stored in ZECC, causing the mango skin to wrinkle. Because respiration rate is related to the rate of quality deterioration, it can be used to estimate the shelf life of fruit after harvest. As stated by Rizkia (2004) that the slower the rate of respiration, the longer the fruit can be stored in its fresh state; conversely, the faster the rate of respiration, the shorter the shelf life.

3.1.2 Skin color

Mangoes are generally observed visually by observing how clearly the color change from green to yellow appears on the mango skin. Mangoes stored at room temperature and in ZECC without treatment/washing (control), as well as those washed with water and detergent + Ca(OH)₂ exhibited no discernible color changes. On the sixth day of observation, the color changed to a slight yellow hue. This color change occurs because mangoes, as climacteric fruits, accelerate the ripening process during storage. The maturation process that occurs concurrently with the breakdown of chlorophyll, resulting in the appearance of other color pigments such as yellow and red, causing the green color to degrade. This is in line with El-Zeftawi *et al.* (1988), who stated that the level of chlorophyll content in green fruit decreases during the storage, other pigments begin to appear, turning the fruit yellow or orange.

3.1.3 Sap and Dirt

For mango fruit washed with water, on day 6 DAW (day after washing), there were still remnants of sap attached to the surface of the mango fruit skin, although they were not particularly noticeable. However, there were a few lenticel spots and a change in color at the fruit's base on day 6 DAW (day after washing) until the 8th day of DAW. While mangoes treated with 1% detergent + 0.25 percent $\text{Ca}(\text{OH})_2$ can visually remove sap, the treatment was more effective at 1% + $\text{Ca}(\text{OH})_2$ 0.5 percent detergent immersion, which resulted in samples of mango fruit being more free of sap and dirt, resulting in a smoother surface with no noticeable changes up to 8 DAW. This is because 1% detergent binds to oil and effectively removes or lifts dirt. Until the eighth day after DAW mango was treated with 1% detergent and 0.5 percent $\text{Ca}(\text{OH})_2$, no lenticel or fungal spots appeared at the base or on the surface of the fruit skin. The surface is smoother and burn-free because the detergent's surfactant active ingredients can remove the oil contained in the sap. Alkaline $\text{Ca}(\text{OH})_2$ solution can neutralize the acid in the sap attached to the golek mango cultivar's skin. This is consistent with Ahmad *et al.* (2017)'s finding that the 1% + $\text{Ca}(\text{OH})_2$ 0.5 percent detergent treatment resulted in a lower mean score for reducing lenticel spots at 2 to 14 DAW when compared to the control. In accordance with Taqiyah (2015), a combination of detergent and $\text{Ca}(\text{OH})_2$ is capable of removing sap and oil from the surface of the Gedong mango skin.

3.2 Second phase of research

The second stage of this study involved determining the quality and shelf life of mangoes while they were stored. Mangoes that received the best washing treatment (1 percent detergent + 0.5 percent $\text{Ca}(\text{OH})_2$) were then given packaging treatment (using Polypropylene (PP) plastic and without packaging) and then analyzed for quality. Mangoes packaged with Polypropylene (PP) plastic can be stored in ZECC for 21 days, whereas mangoes packaged without Polypropylene plastic have a shelf life of only 18 days.

3.2.1 Weight Loss

The results of weight loss analysis are summarised in Fig 1. During storage, the mango fruit's weight loss tends to increase. Unpackaged mangoes (ZT) lost approximately twice as much weight as packaged mangoes (ZK). This means that when packaging is used

in combination with the ZECC storage technique, mangoes lose less weight. Unpackaged mangoes experienced a greater increase in weight loss due to a high evaporation rate (transpiration), whereas packaged mangoes experienced less water evaporation during storage. Water loss results in withering and shrinking. This is consistent with Winarno (2002), who states that the amount of water in foods determines their freshness, appearance and durability. If some of the water in the food evaporates, weight loss occurs, reducing the food's freshness, appearance and durability.

In addition to transpiration, weight loss is also influenced by the respiration process of mango fruit. Carbon loss can occur during the respiration process. Carbon compounds contained in the sugar in mangoes will bind and react with oxygen which will produce simple volatile compounds, namely water vapor and carbon dioxide so that the fruit will lose its weight. So in this case it is known that the respiration process can be suppressed by a combination of packaging and storage in ZECC. This is in accordance with the opinion of Syafutri *et al.* (2006), who stated that the process of fruit respiration can be suppressed by combining packaging and storage at low temperatures.

3.2.2 Hardness Level

The Fig. 2 provides a quantitative analysis of the hardness level of mango. The ripening process of mangoes during storage results in changes in the level of mango fruit hardness. The ripening process in mangoes occurs concurrently with the conversion or degradation of protopectin to pectin, resulting in a decrease in cell wall rigidity. Mangoes without packaging treatment (ZT) had a greater loss of hardness than mangoes with packaged treatment (ZK). This is due to the fact that unpackaged mangoes have a higher respiration rate and a higher enzyme activity. The more actively these enzymes are the softer the texture of the fruit. Meanwhile, the rapid rate of respiration causes the fruit tissue to rupture, resulting in the mango becoming soft. The mango with packaging treatment (ZK) can reduce the amount of oxygen received, thereby slowing the respiration process (maintained). This is consistent with Syafutri *et al.* (2006), who stated that the decrease in hardness is also a result of the respiration and transpiration processes. The respiration process results in the breakdown of carbohydrates into simple compounds and tissue rupture, resulting in the mango becoming soft, whereas the transpiration process

results in water evaporation, resulting in the mango becoming wilted.

3.2.3 Vitamin C Levels

The levels of vitamin C (ascorbic acid) of mangoes during storage in ZECC tend to vary, both packaged in polypropylene plastic and mangoes without packaging as can be seen in Fig 3. The significant increase in vitamin C levels of unpackaged mangoes until the end of storage was in line with the faster ripening process of mangoes compared to packaged mangoes. This is in accordance with Pantastico (1986), who stated that ripe fruit will increase in acidity, and this increase occurs simultaneously with the climacteric pattern, while vitamin C levels will decrease when the maximum point of increase has been exceeded (withering stage). The ripening process of unpackaged mangoes is faster because the respiration process is greater than that of packaged mangoes. Mango packaging can regulate/minimize the respiration process of the fruit so that the freshness of the mango can be maintained. This is in accordance with Park *et al.* (2004), who stated that Polypropylene (PP) plastic has high permeability properties, which can regulate the rate of atmospheric absorption or respiration rate which can maintain fruit freshness longer. The results of analysis of variance showed that mango without packaging treatment and mango with packaging treatment had a significant effect on vitamin C levels during storage. This is indicated by the value of vitamin C which was initially low and then increased until the end of storage. The increase or decrease in vitamin C is because the vitamin is unstable, easily oxidized when exposed to air (oxygen) and this process can be accelerated by storage temperature. This is in accordance with Tannenbaum (1976), stating that the reduction of O₂ will inhibit the degradation of ascorbate into dehydroascorbic acid and H₂O₂ [Tannenbaum (1976)]. The resulting H₂O₂ will cause autoxidation so that it will increase the damage of vitamin C.

3.2.4 Total Acid

The Fig. 4 outlines the results of the total acid level. The total acid value of mango in ZECC storage, both packaged and unpackaged, tends to decrease, though the trend is variable. The percentage of total acid in the fruit decreases as the fruit is stored. The decrease in the percentage of total acid is due to the respiration process's use of organic acids, as well as the use of

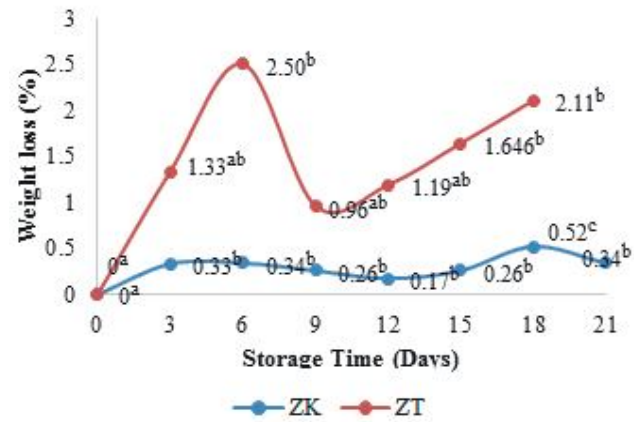


Fig. 1: The weight loss of Mangoes during storage. Values followed by different letters indicate treatment results that are significantly different ($p < 0.05$)

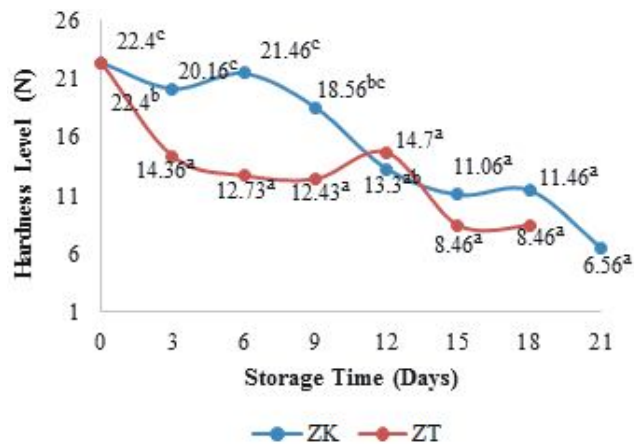


Fig. 2: The Hardness level of Mango fruit during storage. Values followed by different letters indicate treatment results that are significantly different ($p < 0.05$)

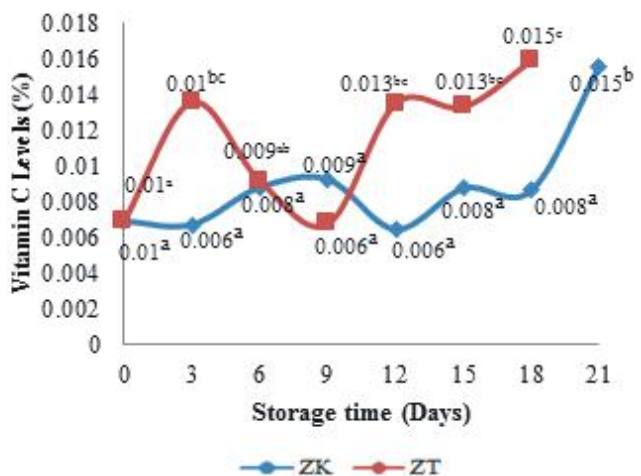


Fig. 3: Vitamin C levels of Mangoes during storage. Values followed by different letters indicate treatment results that are significantly different ($p < 0.05$)

organic acids by microbes in energy-consuming activities. This energy is obtained through the breakdown of the nutrients found in food. Organic acids

are converted to sugars during the respiration process. Khairi *et al.* (2017) found in their research that the fruit's decreased organic acid value indicated that the fruit's ripening metabolism was functioning normally [Khairi *et al.* (2017)].

Total acid in mangoes that were not packaged (ZK) degraded more rapidly than in packaged mangoes (ZK). This is due to the respiration process of unpackaged mangoes. Syafutri *et al.* (2006) stated that when mangoes are not packaged, the respiration process cannot be minimized due to the abundant O_2 in the environment [Syafutri *et al.* (2006)].

3.2.5 Total Dissolved Solids (TDS)

In Fig. 5 we present a detailed evaluation of total dissolved solids. Mangoes' total dissolved solids (packaged and unpackaged) exhibit a fluctuating graph. Unpackaged mangoes (ZT) underwent a maximum ripening process, as indicated by the percentage of TDS value increasing significantly at first and then gradually decreasing until the end of storage. The increase in TDS is a result of starch hydrolysis during ripening process. While the decrease in TDS occurs as a result of the abundant O_2 available in the environment. It may be which contributes to the respiration process. Thus, glucose as the result of starch hydrolysis then was consumed during the respiration process, resulting in a rapid decrease in the sugar content of the fruit. Pantastico (1986) confirmed this by stating that during ripening, starch is hydrolyzed into simple compounds that serve as a source of energy during the respiration process [Pantastico (1986)]. At this point, the sucrose has been converted back to glucose and fructose. The decrease in total sugar content of unpackaged mangoes occurred as the mango fruit began to ripen, at which point the starch content began to decrease and the activity of the invertase enzyme decreased, resulting in a decrease in sugar content. The mango with packaging (ZK) has the ability to maintain the fruit's ripening process, as indicated by the predominant fluctuating TDS value. This demonstrates that by combining packaging and storage in ZECC, the rate of decrease in the percentage of TPT in mangoes can be slowed.

This variable total dissolved solids value is also a result of the fruit's non-uniform maturity level. Non-uniform fruit ripeness causes abnormal respiratory activity so that the breakdown process of simple sugars varies. In general, changes in total dissolved solids

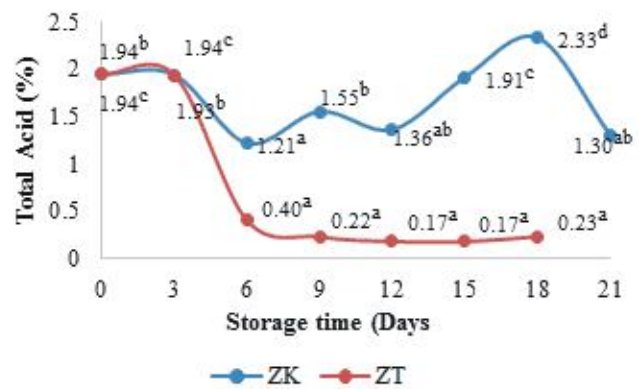


Fig. 4: Total acid level of Mango fruit during storage. Values followed by different letters indicate treatment results that are significantly different ($p < 0.05$)

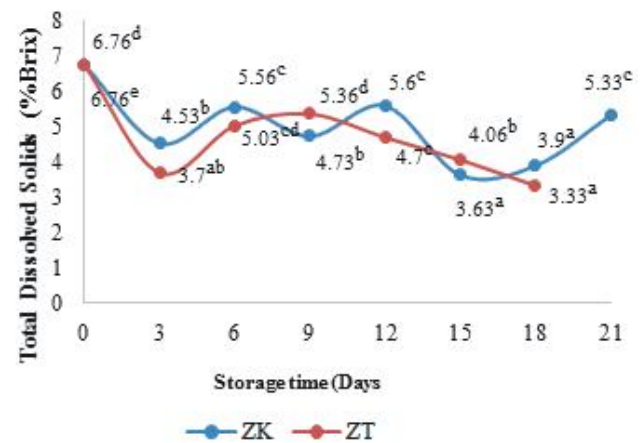


Fig. 5: Total dissolved solids of mango fruit during storage. Values followed by different letters indicate treatment results that are significantly different ($p < 0.05$)

content increased at the maximum point of storage and then decreased until the fruit began to rot on the final day of storage. This is consistent with Biale and Young's (1971) observation that the general trend is for a rapid increase in sugar content followed by a decline; in climacteric fruit, this condition becomes a marker.

3.2.6 Degree of Acidity (pH)

According to the Fig. 6, mango fruit are acidic, with a pH value ranging between 2 and 6 during storage. The ripening of mangoes alters the pH value of the fruit. Without packaging treatment (ZT), mango matured rapidly (maximum), increasing the pH value. It is not the case with packaged mangoes (ZK), as their ripening process is slowed, resulting in a stable pH value throughout storage. As the mango ripens, the acid content decreases while the simple sugars increase, as indicated by the decrease in total acid content. The pH value is directly proportional to vitamin C levels and

inversely proportional to total acidity. This is consistent with Khairi *et al.* (2017), who stated that changes in pH indicate changes in the composition of the fruit's cell fluid as it matures; the pH value that tends to be high is related to relatively high ascorbic acid (vitamin C) levels during storage. This change indicates that the fruit's metabolism affects the pH value [Khairi *et al.* (2017)].

3.2.7 Water content

The water content of mangoes stored in the ZECC method varied slightly during storage that we can see in Fig. 7. When compared to unpackaged mangoes, packaged mangoes (ZK) are able to maintain changes in water content during storage. This is because PP packaged mangoes have a high permeability, which minimizes changes in water content during storage. This is consistent with Schwartz (2009), who stated that because of the packaging, ambient air cannot easily enter the material, thereby inhibiting the process of water exchange during storage.

Due to the high humidity in ZECC storage, which reached 80-90 percent, mango fruit experienced an increase and decrease in water content during storage. Due to the high humidity level in the ZECC room, moisture absorption from the environment into the stored mango is possible. The longer the storage time, the higher the water content will remain. According to Herawati (2008), a significant factor influencing the decline in the quality of food products is changed in the product's water content, which can be influenced by the room's temperature and humidity during storage. This opinion is backed up by Retnani *et al.* (2009) who stated that the high humidity of the storage room can result in the absorption of water vapor from the air into the foodstuffs, resulting in an increase in water content.

Additionally, the increase in water content during storage is a result of the mangoes' respiration process. During storage, the fruit undergoes a ripening process that includes the conversion of starch to simple sugars ($C_6H_{12}O_6$). These simple sugars then interact with the oxygen (O_2) in the chamber, increasing the rate of water (H_2O) formation in the fruit. This is consistent with Rizkia (2004), who stated that one of the causes of changes in the water content of fruit is the respiration process, during which water is formed as a result of sugar reorganization into simpler compounds.

3.2.8 Color

Based on the results in Fig. 8, we make the following observations. The L^* value indicates the brightness level of the mango fruit, which indicates the reflected light that produces achromatic colors of white, gray and black, *i.e.* from a value of 0 (black)-100 (white). The L^* value of unpackaged and packaged mangoes had a very small decrease in lightness value during storage. The range of changes in the L^* value from 65-62 indicates a slight decrease in brightness level during storage. The longer the fruit is stored, the lower the brightness level of the mango. According to Ahmad *et al.* (2014), that the brightness level of the color will decrease which will be directly proportional to the longer the shelf life, the fruit will lead to spoilage in the end. The decreasing brightness level of the mango skin color is caused by changes in the chlorophyll content of the fruit. This is in accordance with the statement of Syafutri *et al.* (2006), who stated that the reduced level of color brightness in fruit during storage is caused by reduced chlorophyll content in fruit skins and the appearance of carotenoids.

The a^* value is a value that shows the gradation of green to red. A mixed red-green chromatic color with a value of $+a^*$ (positive) from 0 to +80 for red and a value of $-a^*$ (negative) from 0 to -80 for green. The a^* value of mango tends to increase during the storage process. Mangoes tend to be green, indicated by an a^* value below 0, but the longer the storage time, the color of the fruit moves to red. The significant increase in a^* value was caused by the high respiration rate of unpackaged mangoes so that the degradation of chlorophyll was also rapid which had the effect of accelerating the synthesis of pigment (color change) of the fruit. This is in accordance with the opinion of Masfufatun *et al.* (2009), who stated that a high respiration rate will also cause chlorophyll degradation and pigment synthesis to be fast, consequently accelerating color changes.

The b^* value indicates the color gradation to yellow. A mixed blue-yellow chromatic color with $+b^*$ (positive) value from 0 to +70 for yellow and $-b^*$ (negative) value from 0 to -70 for blue. Based on the Fig. 8, it shows that unpackaged mangoes have a slowly increasing b^* value during storage compared to packaged mangoes whose b^* values tend to be stable until the end of storage. The results of the measurement of the b^* value show

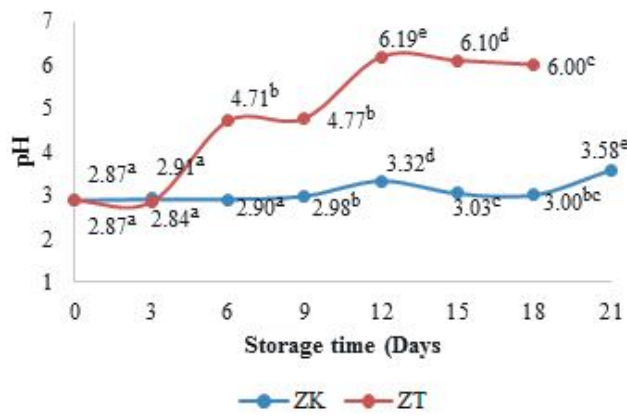


Fig. 6: pH value (Degree of acidity) Mango fruit during storage. Values followed by different letters indicate treatment results that are significantly different ($p < 0.05$).

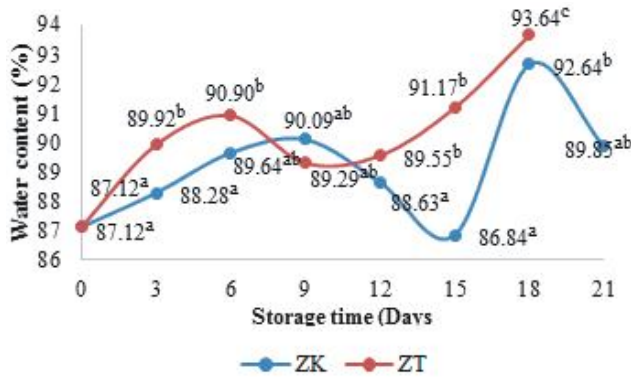


Fig. 7: Water content of mangoes during storage. Values followed by different letters indicate treatment results that are significantly different ($p < 0.05$).

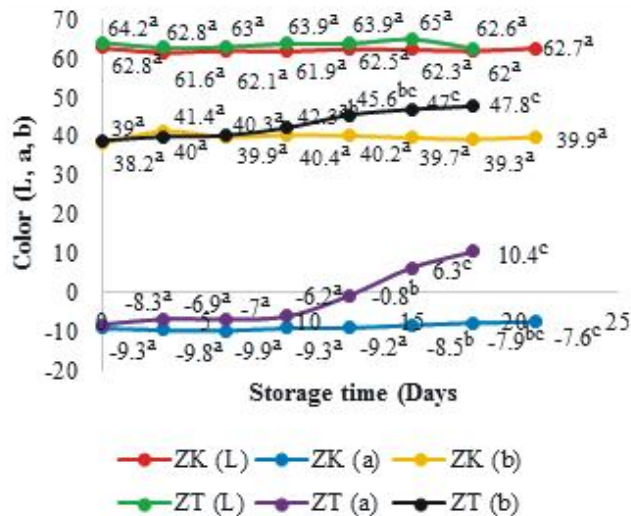


Fig. 8: Analysis of mango skin color during storage. Values followed by different letters indicate treatment results that are significantly different ($p < 0.05$).

that the longer the storage, the yellow color of the mango will be clearer. The increasing b^* value in unpackaged mangoes indicates that the fruit is getting more mature than the packaged mangoes during storage.

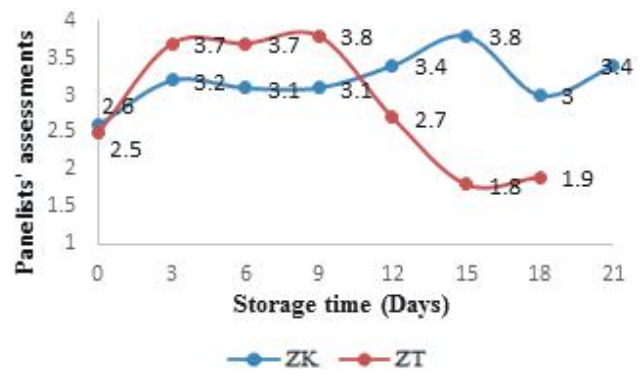


Fig. 9: Results of Organoleptic testing on mango color in ZECC storage

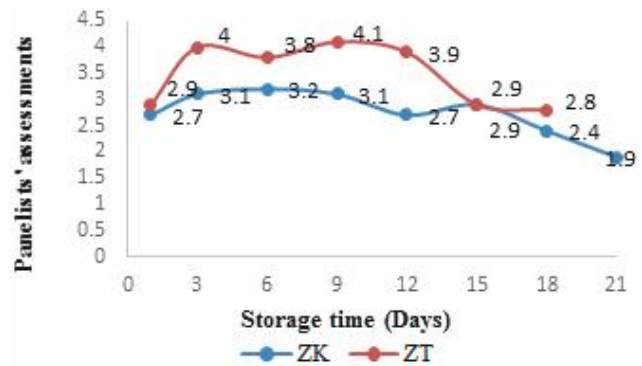


Fig. 10: Results of organoleptic testing on mango aroma in ZECC storage

3.2.9 Organoleptic test

Color: The Fig. 9 summarises and discusses the main findings of the of organoleptic color. The changes in panelists' assessments of organoleptic color parameters in mangoes were due to the nature of mangoes undergoing post-harvest ripening (after harvesting), specifically that the color will change during the storage process due to chlorophyll degradation into other pigments. The panelists' assessment of mangoes with packaging treatment (ZK) tended to remain stable until the end of storage, with an average value of 3 (slightly similar), whereas mangoes without packaging (ZT) maintained an average value of 4 (similar) until the ninth day of storage, when it decreased until the end of storage. This demonstrates that mangoes treated with packaging can help preserve or delay the color change of mangoes stored in ZECC. Packaging treatment on mangoes can slow the respiration process, resulting in a slower color change and maturation and aging process. This is consistent with Ali (2017), who stated that a faster respiration rate can accelerate the senescence process, which results in a more rapid color change.

Aroma: The panelists' evaluations of the mango

aroma parameters revealed a range of results but a consistent pattern of increasing and then decreasing until the end of storage. In terms of fruit aroma, panelists prefer the unpackaged aroma of mango fruit as can be seen in Fig. 10.

The high acceptance of unpackaged mango aroma (ZT) is a result of the increasing ripening process (perfect ripening), which results in an increase in the production of volatile components.

While, the packaged mango (ZK) took longer to decompose, the panelists generally disliked it due to the incomplete ripening process, which resulted in a low flavor. This is consistent with Muchtadi (1992), who stated that ripening typically results in an increase in the content of simple sugars, which imparts a sweet flavor, as well as an increase in the production of volatile substances, which imparts a distinctive fruit flavor.

Taste: The results of the taste are summarised in Fig. 11. The results of organoleptic taste on mangoes stored at ZECC showed that the panelists' assessment of fruit taste increased and then decreased until the end of storage. The range of values between 3-5 (based on the graph) shows that the panelists' assessment of unpackaged mangoes (ZT) is dominantly preferable to mangoes with packaged treatment (ZK) with a value of 2-3. The high rating for unpackaged mangoes is because the mangoes undergo an even ripening process during storage, resulting in a distinctive taste and good color which are preferred by panelists [Ali (2017)]. The sweet taste is due to the change in the starch content of the fruit to sugar during storage. This is in accordance with the statement of Mulyati (2012), that changes during the ripening process are changes in starch and fat reserve materials into various sugars. The mango with packaging (ZK) undergoes a slow ripening process due to its low respiration rate in the presence of packaging, but it takes longer to decay or damage in ZECC storage.

Texture: Fig. 12 illustrates results of mango's texture. Panelists determined that mango with packaged treatment (ZK) (mean value 3-4) was preferable in terms of texture because the level of hardness did not decrease significantly (soft), as opposed to mango without packaged treatment (ZT) (mean value 2-3). The texture began as hard, which the panelists disliked, then softened slightly, which the panelists liked, and finally became extremely soft due to damage/rotting,

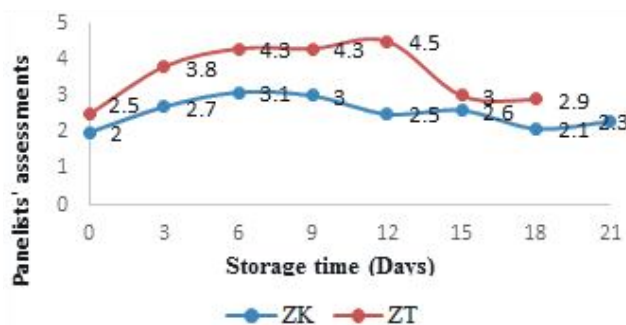


Fig. 11: Results of organoleptic testing on mango taste in ZECC storage

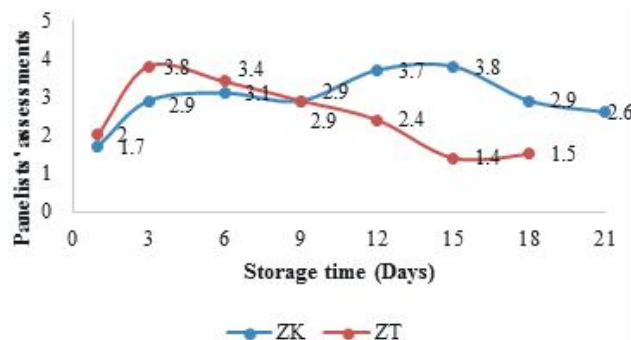


Fig. 12: Results of organoleptic testing on mango texture in ZECC storage

which the panelists disliked. When the qualitative (organoleptic test of texture parameters) analysis of mango fruit is combined with quantitative analysis (with a penetrometer), it is discovered that the level of hardness (the process of hardness decreasing) is directly proportional during storage.

Mangoes' softening texture is caused by the ripening process that occurs during storage. Maturation occurs concurrently with the conversion or degradation of insoluble protopectin to soluble pectin. The reshuffle occurs as a result of the action of enzymes such as pectin methyl esterase, which softens the fruit. Protopectin levels in the fruit decrease as the fruit ripens, while pectin levels increase. This is in accordance with Johansyah and Kusdiantini (2014), that as fruit ripens and stores, some of the water-insoluble protopectin converts to water-soluble pectin, reducing the cohesion of the cell walls that connect cells, resulting in a decrease in texture or fruit hardness and the fruit becoming soft [Johansyah and Kusdiantini (2014)]. Additionally, the rate of respiration has an effect on the degree of hardness or texture. Unpackaged mangoes with a high respiration rate cause the fruit's tissue to rupture and enzyme activity to accelerate, resulting in a softer fruit texture. The mango with packaging treatment (ZK) can reduce the amount of oxygen

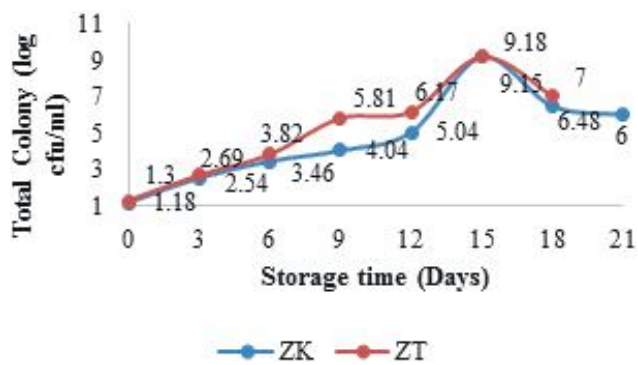


Fig. 13: Mold and yeast cell count on mangoes during storage in ZECC

received, thereby slowing the respiration process (maintained).

3.2.10 Microbial Analysis (Yeast Mold Count)

According to the Fig. 13, the results of microbial analysis (mold and yeast counts) on mango fruit storage in ZECC indicated that yeast mold growth continued to increase and then decreased gradually until the end of storage. Microbial growth (mold and yeast) that began low/small and then increased to a maximum growth peak on the 15th day generally indicated that the mangoes' quality deteriorated during storage and gradually entered the senescence phase. This also demonstrates that mangoes with a relatively high sugar content and a low pH provide an ideal environment for molds and yeasts to grow to their maximum growth capacity during storage. This is consistent with Rawat (2015) statement that fruit with a high sugar content and a low/acidic pH (pH range between 3-8) promotes the growth of fungi (mold/yeast) after the fruit is harvested .

Mango without packaging (ZT) exhibited a greater increase in the growth of the dominant mold/yeast than mango with packaging (ZK). This demonstrates that by combining calcium hydroxide washing with packaging on mangoes stored in ZECC, the rate of microbial growth can be slowed or suppressed, thereby extending the fruit's life phase. Certain microbes require oxygen to grow, which can be suppressed through packaging. This is consistent with the opinion of Mulyawanti *et al.* (2017), who stated that treating fruit with packaging technology can suppress the air activity required by microbes, thereby slowing the growth rate of pathogenic microbes [Mulyawanti *et al.* (2018)].

4. Conclusion

It can be concluded that analysis of the quality of

golek mango (*Mangifera indica* L.) physically, chemically, microbiologically, and sensory in the Zero Energy Cool Chamber (ZECC) storage technique shows that ZECC can maintain optimal fruit quality through a washing treatment process (chemically) in combination with packaging. In addition, the Zero Energy Cool Chamber (ZECC) storage method with a combination of washing and packaging treatments is effective in maintaining the quality of mangoes up to 21 days of storage.

Acknowledgment

This research was funded by the Directorate General of Research and Development, Ministry of Research, Technology and Higher Education, Republic of Indonesia, through LPPM Unhas : Penelitian Terapan 2020 Number 7/E1/KP.PTNBH/2021.

References

- Ahmad, Sutopo, Roedhy Poerwanto and Suryo Wiyono (2017). Keefektifan Bahan Pencuci Dan Pencegah Penyakit Terhadap Kualitas Buah Mangga cv. Gedong Gincu Dan Arumanis (The Effectiveness of Washing Materials and Disease Protecting Agent on the Quality of Mango Fruit cv. Gedong Gincu and Arumanis). *Jurnal Hortikultura*, **27(2)**, 253-260.
- Ahmad, Usman, Emmy Darmawati and Nur Rahma Refilia. (2014). Kajian Metode Pelilinan Terhadap Umur Simpan Buah Manggis (*Garcinia mangostana*) Semi-Cutting Dalam Penyimpanan Dingin. *Jurnal Ilmu Pertanian Indonesia*, **19(2)**, 104-110.
- Ali, Kamilia Nur Yaumil (2017). Mutu Buah Mangga (*Mangifera indica* L.) Dan Tomat (*Lycopersicon esculentum* Mill.) Yang Disimpan Pada ZECC (Zero Energy Cool Chamber). Universitas Hasanuddin.
- Biale, J.B. and R. Young (1971). *The Avocado Pear. Dalam Hulme, A.C. The Biochemistry of Fruit and Their Produce*. London: Academic Press.
- Dirpan, A. (2019). The Quality of Tomato (*Lycopersicon esculentum* Mill.) Stored on ZECC (Zero Energy Cool Chamber). P. 12012 in *IOP Conference Series: Earth and Environmental Science*. Vol. 270. IOP Publishing.
- Dirpan, Andi (2018). *ZECC (Zero Energy Cool Chamber) Penyimpanan Dingin Yang Murah Dan Ramah Lingkungan Untuk Memperpanjang Masa Simpan Buah Dan Sayur Setelah Panen*. Makassar: Universitas Hasanuddin.
- Dirpan, Andi, Muhammad Tahir Sapsal, Abdul Kadir Muhammad, Mulyati M. Tahir and Rahimuddin (2017). Evaluation of Temperature and Relative Humidity on Two Types of Zero Energy Cool Chamber (ZECC) in

- South Sulawesi, Indonesia. *IOP Conference Series: Earth and Environmental Science*, **101**, 012028.
- El-Zeftawi, B.M., L. Brohier, L. Dooley, F.H. Goubran, R. Holmes and B. Scott (1988). Some Maturity Indices for Tamarillo and Pepino Fruits. *J. Horticult. Sci.*, **63(1)**, 163-169.
- Herawati, Heny (2008). Penentuan Umur Simpan Pada Produk Pangan. *Jurnal Litbang Pertanian*, **27(4)**, 124-130.
- Islam, M.P. and T. Morimoto (2015). Science Direct Evaluation of a New Heat Transfer and Evaporative Design for a Zero Energy Storage Structure. *Solar Energy*, **118**, 469-484.
- Islam, M.P., T. Morimoto and K. Hatou (2013). Dynamic Optimization of inside Temperature of Zero Energy Cool Chamber for Storing Fruits and Vegetables using Neural Networks and Genetic Algorithms. *Computers and Electronics in Agriculture* **95**, 98-107.
- Johansyah, Afrazak and Endang Kusdiantini (2014). Pengaruh Plastik Pengemas Low Density Polyethylene (LDPE), High Density Polyethylene (HDPE) Dan Polipropilen (PP) Terhadap Penundaan Kematangan Buah Tomat (*Lycopersicon esculentum* Mill). *Anatomi Fisiologi*, **22(1)**, 46-57.
- Khairi, Amalya Nurul, Affan Fajar Falah and Agung Putra Pamungkas (2017). Analisis Mutu Pascapanen Melon (*Cucumis melo* L.) Kultivar Glamour Sakata Selama Penyimpanan. *CHEMICA: Jurnal Teknik Kimia*, **4(2)**, 47-52.
- Masfufatun, Widaningsih, N. Kumala and T. Rahayuningsih (2009). Pengaruh Suhu Dan Waktu Penyimpanan Terhadap Vitamin C Dalam Jambu Biji (*Psidium guajava*). *Universitas Wijaya Kusuma, Surabaya*.
- Muchtadi, Deddy (1992). *Fisiologi Pasca Panen Sayuran Dan Buah-Buahan: Petunjuk Laboratorium*. Institut Pertanian Bogor.
- Mulyati (2012). *Sayur-Sayuran, Buah-Buahan Penanganan Dan Pengolahannya*. Makassar: CV. Indo media.
- Mulyawanti, Ira, Enrico Syaefullah and Dwi Amiarsi (2018). Teknologi Pengemasan Atmosfir Termodifikasi (Modified Atmosphere Packaging/Map) Dan Vakum Pada Buah Durian.
- Pantastico, E.B. (1986). *Fisiologi Pascapanen, Penanganan Dan Pemanfaatan Buah-Buahan Dan Sayur-Sayuran Tropika Dan Subtropika* (Terjemahan Kamariyani 1997). Yogyakarta: Gajah Mada University Press.
- Park, T., Y.A. Kim and J. Yun (2004). The Need for Collaboration in the Supply Chain for Successful Direct Shipments. In : *Proceedings of the Thirty-Third Annual Meeting of the Western Decision Sciences Institute*.
- Rawat, Seema (2015). Food Spoilage: Microorganisms and Their Prevention. *Asian J. Plant Sci. Res.*, **5(4)**, 47-56.
- Retnani, Y., W. Widiarti, I. Amiroh, L. Herawati and K.B. Satoto (2009). Daya Simpan Dan Palatabilitas Wafer Ransum Komplit Pucuk Dan Ampas Tebu Untuk Sapi Pedet. *Media Peternakan*, **32(2)**, 130-136.
- Rizkia (2004). Kajian Laju Respirasi Dan Perubahan Mutu Buah Mangga Gedong Gincu Selama Penyimpanan Dan Pematangan Buatan. Institut Pertanian Bogor.
- Schwartz, Naomi (2009). Pengaruh Jenis Bahan Pengemas Terhadap Kualitas Cabe Merah Segar Selama Penyimpanan Dingin. Universitas Sumatra Utara.
- Syafutri, Merynda I., F. Pratama and D. Saputra (2006). Sifat Fisik Dan Kimia Buah Mangga (*Mangifera Indica* L.) Selama Penyimpanan Dengan Berbagai Metode Pengemasan. *Jurnal Teknologi Dan Industri Pangan*, **17(1)**, 1-11.
- Tannenbaum (1976). *Vitamins and Mineral*. New York (US: Merceel Dekker.
- Taqqiyah, Affifah (2015). Pengaruh Penambahan Fungisida Pada Bahan Pencuci Serta Suhu Penyimpanan Terhadap Peningkatan Kualitas Mangga (*Mangifera indica* L.).
- Winarno (2002). *Fisiologi Lepas Panen Produk Hortikultura*. Bogor: M-Brio Press.